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POR-2511
(WT-2511)

Operation ROLLER COASTER

PROJECT OFFICERS REPORT—PROJECT 2.8

OFF-SITE SURVEY

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Issuance Date: September 17, 1968

[redacted]

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ABSTRACT

Operation Roller Coaster was a joint United States and United Kingdom experiment to determine plutonium hazards from accidents with plutonium bearing weapons. Four chemical detonations involved such weapons. The U. S. Public Health Service, through a Memorandum of Understanding with the U. S. Atomic Energy Commission and in conjunction with Project Roller Coaster, provided off-site radiological health surveillance. Detectable quantities of plutonium were released to off-site locations, but contamination levels did not present a significant hazard. Sampling methods are described and discussed with recommendations. The biological significance of plutonium is related to hazard evaluation. Certain recommendations are discussed for emergency procedures in the event of an accident.

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CHAPTER 1

INTRODUCTION

Operation Roller Coaster was a joint US/UK series of four non-nuclear detonations of plutonium bearing weapons. The project was designed to supply empirical information concerning the nature and extent of the resultant alpha contamination and to help establish criteria for the transport and storage of such weapons. Studies of a similar nature were conducted as part of Operation Plumbob (Test Group 57) in 1957.

The four events in this series and their firing dates were:

Double Tracks	0255 May 15, 1963
Clean Slate I	0417 May 25, 1963
Clean Slate II	0347 May 31, 1963
Clean Slate III	0330 June 9, 1963

Three of the events, Double Tracks and Clean Slate I and III, released plutonium to off-site areas in detectable quantities.

Under a Memorandum of Understanding between the U. S. Atomic Energy Commission (AEC) and the U. S. Public Health Service (PHS) an Off-Site Radiological Safety Organization was established in 1954 to conduct radiological surveillance of the area within a 300-mile radius surrounding the Commission's Nevada Test Site. The Off-Site Radiological Safety Program conducts radiological monitoring and environmental sampling in the off-site areas surrounding the restricted area enclosed within the Nevada Test Site and the Nellis Air Force Range. This overall complex of the Nevada Test Site (NTS) and the Nellis Air Force Range (NAFR) includes the Nuclear Rocket Development Station (NRDS) and the Tonopah Test Range (TTR) and for simplicity will be called the test range complex throughout this report. For Operation Roller Coaster, the facilities of Sandia Corporation's Tonopah Test Range were utilized. Although routine sampling and monitoring is conducted around the test range complex, surveillance may be extended as necessary to provide more detailed coverage.

A vast number of experiments with very detailed analysis were conducted as part of the Project.[7] This report is not an evaluation of these experiments but is a presentation of the radiation environment in public areas surrounding the test range complex based on the analysis of samples gathered by the U. S. Public Health Service. Some of these samples were investigated at the Southwestern Radiological Health Laboratory while others entered the general sample handling machinery of the Project.

To insure parallel objectives and paths, a referee team was chosen by the scientific director of operations for Roller Coaster to provide recommendations to the functions of the Project. The team arranged for cross laboratory checks with blanks, blind duplicates, spikes, and standards. Several specific recommendations for radiochemistry were given:

1. Yield in analysis should be determined by ^{236}Pu tracer.
2. Yields should not be less than 60%.
3. All samples should be completely dissolved for any radiochemistry.

CHAPTER 2
PROCEDURES

The Off-Site Radiological Safety Program maintains a network of air sampling and dosimetry stations in the off-site area and samples milk and water on a routine schedule. The extent and frequency of monitoring was increased greatly during Operation Roller Coaster, and new techniques were initiated to adequately measure alpha contamination.

2.1 GROUND MONITORING

Prior to Operation Roller Coaster, selected roads in the general vicinity were posted with marking stakes to be used as references for ground monitoring and sampling locations. Figures 2.1 and 2.2 illustrate the numbering systems used.

Ground monitors used Eberline PAC-3G proportional alpha counters, PAC-1S scintillation alpha counters, and Victoreen Thyac Geiger-Mueller detectors. The latter instruments were available for any unforeseen emergency; no β-γ readings above background were observed.

The PAC-3G has three scale ranges, x1, x10, x100, with a maximum capability of 100,000 cpm. The total window area is about 61 cm^2, but the sensitive area is only 55 cm^2. The sensitive volume contains propane gas and has an aluminized mylar window about 1 mg/cm^2 thick. This instrument has an auxiliary probe cover which decreases the efficiency by a factor of 20 and allows the range to extend to 2,000,000 cpm. The PAC-1S has four ranges, x1, x10, x100, x1000, with a direct readout to

2,000,000 cpm over 60 cm^2 probe area. The probe face is aluminized mylar backed with thin layers of dutch leaf to prevent light leaks to the ZnS phosphor present in a thin layer. A prism/lens concentrates and directs the light pulses to the photocathode of the photomultiplier tube located in the probe handle.

Both types of instruments were calibrated to indicate 1 cpm for every 2 dpm of the plutonium calibration standards.

Due to the intricacies of alpha monitoring, all PHS monitors active in Operation Roller Coaster participated in a refresher training program which included field exercises in plutonium alpha monitoring. If an indication of less than 50 cpm was encountered in monitoring, earphones were used and the number of clicks was counted for one minute. Whenever higher readings were encountered, a paper shield was placed over the probe to ensure the PAC-3G's were not beta sensitive. Light sensitivity of the PAC-1S probes was frequently checked by turning the probes toward the sun and observing any instrument deflection.

Rough quantitative estimates of deposition can be made on the basis of the conversion table in Figure 2.3 (published by NRDL) and the curve in Figure 2.4 from Test Group 57 Interim Test Reports.

2.2 FALLOUT COLLECTORS

Two types of fallout collectors were used to represent an ideal surface to catch particles dropping during cloud passage. The first was a 12 by 12-inch cellophane surface called a film collector, and the second a 50 mm by 75 mm glass microscope slide. Both were coated with canada balsam to fix particulate to the surface. These collectors were placed at various reference stakes on platforms three feet above the ground.

The film collectors were analyzed primarily for plutonium activity and were the subject of radiochemical analysis described later in this section. The glass slides were submitted for special particulate analysis including phosphor autoradiography, nuclear track autoradiography, and optical and electron microscopy.

Table 2.1 shows the number of film collectors and glass slide samples selected for analysis.

(See Table 2.1)

Four laboratories processed the film collectors: Eberline Instrument Company, Tracerlab, Hazelton-Nuclear Science Corporation, and Isotopes Incorporated, with the latter performing the special particulate analysis of U. S. Public Health Service samples.

2.3 COLLECTOR RADIOCHEMISTRY

The four laboratories providing this service did have some variations in their individual radioanalytical procedures, but their objective and the overall standardization requirements were the same for all.

The samples were dissolved completely including any organic material or silicates; ^{236}Pu was added as a tracer for yielding or percentage recovery information, and the solutions passed through ion exchange columns. The plutonium was eluted from the column and the plutonium electroplated from the resultant solution.

The equipment used for alpha particle energy spectra varied among the laboratories; however, the peaks of primary interest were observed by all; they included: ^{238}Pu (5.49 Mev), ^{239}Pu (5.15 Mev), ^{240}Pu (5.12 and 5.15 Mev) and the tracer, ^{236}Pu (5.76 Mev). Calculations were based upon the 5.15 Mev peak common to ^{239}Pu and ^{240}Pu.

ISOTOPES, INC. SPECIAL PARTICULATE ANALYSIS

Sixteen of the glass deposition slides from the off-site array were selected for special particulate analysis by Isotopes, Inc. The three methods used were phosphor intensification autoradiography, nuclear emulsion alpha track autoradiography with optical microscopy, and electron microscopy with nuclear track autoradiography. Detailed information of procedures may be found in WT 2507.[15]

2.4 AIR SAMPLING

Air samples were taken with Staplex and General Metal Works high volume air samplers using Gelman type E glass fiber filters. Flow rates ranged from 40 to 60 cfm as measured with rotameters. The average flow rate over the sampling period was used to determine total air sampled. Nineteen air sampling stations were located in public areas, and five were in the test range complex. Figures 2.1 and 2.2 show air sampling locations. Some sampling locations changed during the series, as shown in the sample results.

The glass fiber filters contain a small amount of organic fiber for strength and were later discovered to contain 1.8 to 5.06μgm U_3O_8 per filter.[10] The efficiency of the filter at optimum flow rates is 99.6% for particles larger than 0.25μ and greater than 98% for particles as small as 0.05μ.[6] Efficiency tests for this filter showed 0.03% penetration using 0.3μ DOP aerosol.

Each filter was first gross alpha counted on a Nuclear Chicago Model 193A Ultrascaler using an Eberline Instrument Co. large area probe with an effective area of 49.98in.^2. The instruments were calibrated with low and high count rate standards; mapping various segments of the chamber resulted in an average observed efficiency of 24%. The ratio of the probe area to sample area was 0.79. Thus the approximate conversion of alpha monitor cpm to actual dpm was approximately $\frac{1}{.24} \times \frac{1}{.79} \cong 5.3$ (see Appendix D).

Filters showing alpha activity above background were sent to Tracerlab for radiochamical analysis for $^{239,240}Pu$ and for uranium fluorimetry. A Jarrell-Ash fluorometer was used.

TABLE 2.1 SAMPLES SELECTED FOR ANALYSIS

Event	Glass Slides	Film Collectors
Double Tracks	7	150
Clean Slate I	5	30
Clean Slate II	4	9
Clean Slate III	0	5

Figure in pocket at end of report

Figure 2.1 Marking stake numbering system, Double Tracks event.

Figure in pocket at end of report

Figure 2.2 Marking stake numbering system, Clean Slate I, II, and III.

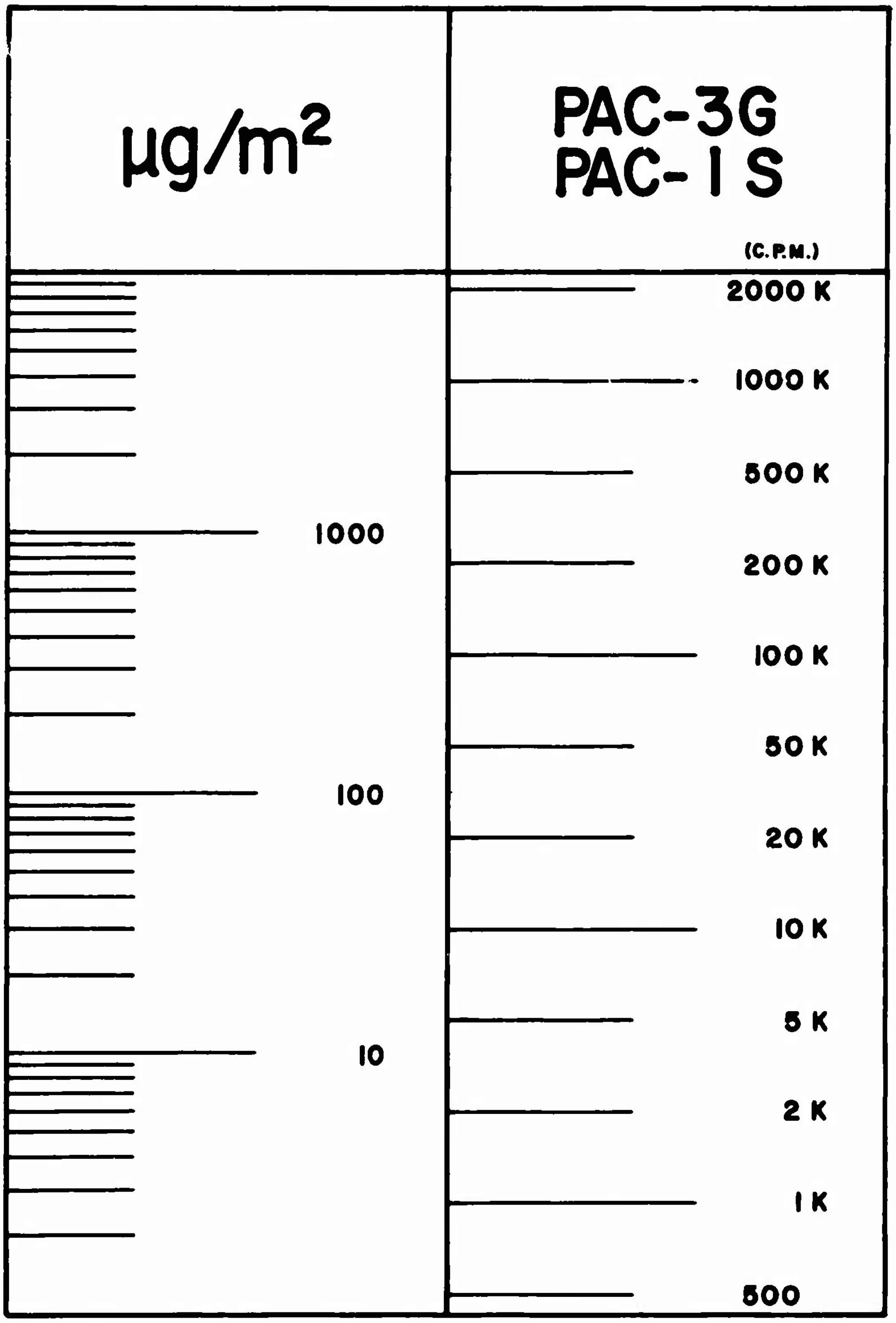

Figure 2.3 Survey instrument conversions to $\mu g/M^2$.

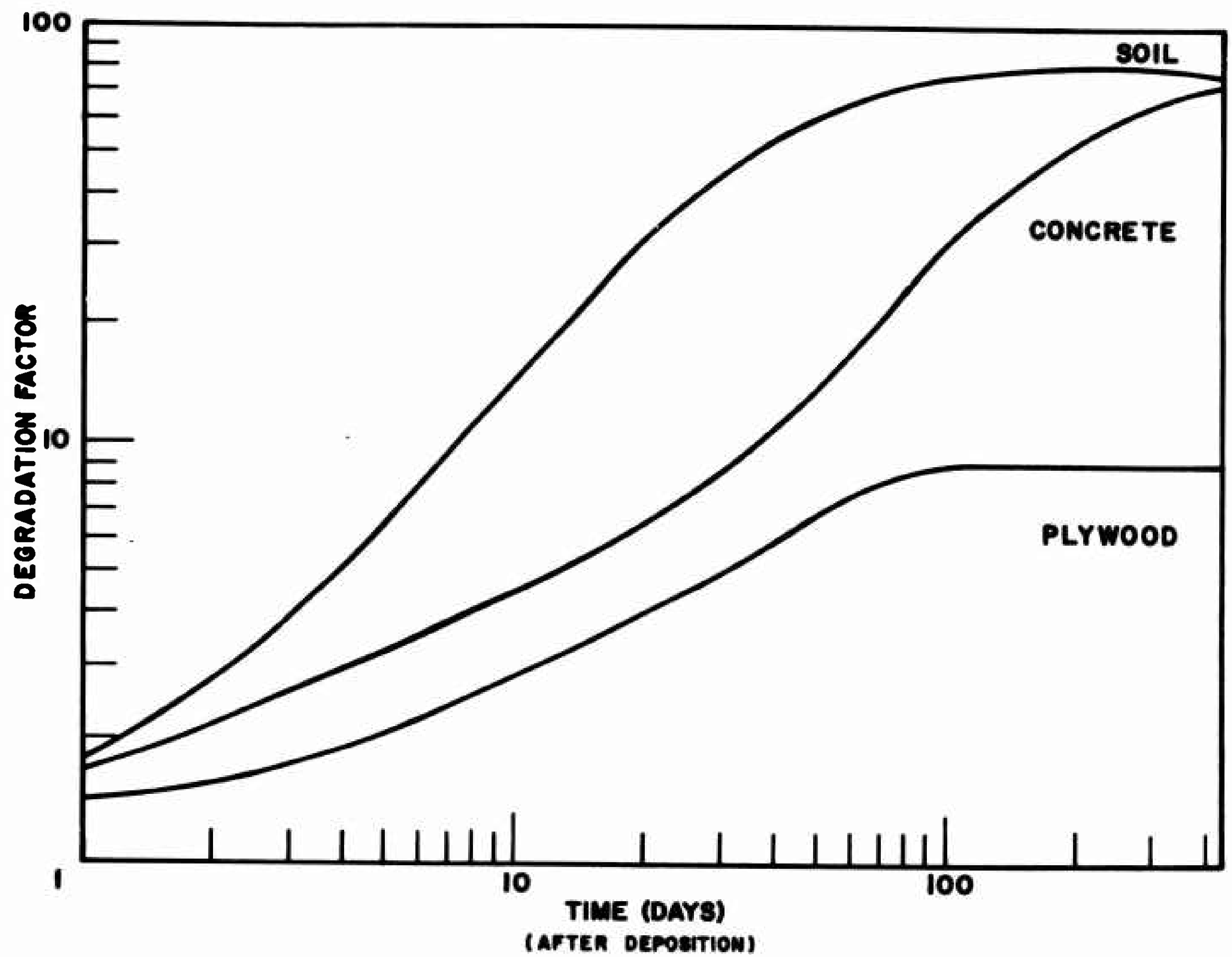

Figure 2.4 Activity degradations apparent to alpha survey instruments (Pu).

CHAPTER 3
RESULTS

3.1 DOUBLE TRACKS

3.1.1 Ground Monitoring

The highest surface contamination levels, on the order of 2,000 dpm/ft^2, were discovered in the area of Stakes 259 to 262 on the test range complex (Figure 2.1). At Stonewall Springs (Stake 305), at the edge of the test range complex, an indication of 300 dpm/ft^2 was observed. Along Highway 95 from Stake 15 to Stake 103 (generally from Goldfield to Springdale), very low but detectable quantities were observed with the survey instruments. Complete ground monitoring results can be found in Appendix A.

3.1.2 Fallout Collectors

Film Collectors

Sample locations on the test range complex from Stakes 250 to 262 showed the greatest concentrations with 3310 to 56,100 dpm/ft^2 $^{239,240}Pu$ per sample. The greatest contamination levels found off-site were generally from Scotty's Junction south on Highway 95 to Springdale with four peak areas: Stakes 51 to 80 averaged 5124 dpm/ft^2; Stakes 85 to 90 averaged 1230 dpm/ft^2; a peak of 2154 dpm/ft^2 occurred at Stake 92; Stakes 101 to 103 averaged 1520 dpm/ft^2. Complete results for the Double Tracks Film Collector Analysis can be found in Appendix B. The dual data by

Eberline Instrument Company were re-runs to achieve 60% recovery of ^{236}Pu tracer.

Glass Slide Collectors

Only seven glass slides were selected for Special Particulate Analysis by Isotopes, Inc. The samples were from Stakes 57, 61, 259, 260, 261, and 262. The latter four were from areas of higher activity on the test range complex. The remaining samples farther downwind in public areas showed only seven total autoradiographic images on the three samples. Complete results for the seven samples are given in Appendix C.

3.1.3 Air Sample Results

For the Double Tracks event, 44 special air samples were taken at 24 locations. Five samples were taken on the test range complex and 15 were taken at population centers. The gross alpha counting performed by the Southwestern Radiological Health Laboratory showed significant activity on several filters. Additional radiochemical analysis of these air samples by Tracerlab showed the activity to be due almost entirely to $^{239,240}Pu$.

Table 3.1 summarizes the most significant samples following the Double Tracks event. In each case, air concentrations dropped sharply during successive sampling periods. Complete air sample results can be found in Appendix D.

3.2 CLEAN SLATE I

3.2.1 Ground Monitoring

Following Clean Slate I, roads were monitored as shown in Figure 2.2. Positive results as high as 1200 dpm/ft^2 on a survey meter were measured along the road between Reed and Diablo, although there were no detectable levels at either of these locations. The highest levels on the test range complex were observed between Stakes 816 to 824 and from the vicinity of Cedar Pass to four miles east of Cedar Pass. Complete monitoring results for Clean Slate I are tabulated in Appendix A.

3.2.2 Fallout Collectors

Film Collectors

All film collectors selected for analysis were from Stakes 801 to 830, on the test range complex. The higher concentrations were observed from Stakes 812 to 830, with 816 to 823 the highest locations. Complete film collector results are tabulated in Appendix B.

Glass Deposition Slides

Five glass slides were selected for special particulate studies from the areas of highest activity on the test range complex. These were from Stakes 817, 819, 820, 822, and 824. A number of particles were observed, and these samples can be used to complete the overall special particulate study. Results of Special Particulate Analysis of Off-Site

Samples can be found in Appendix C. For more complete information on the Special Particulate Analysis, see Operation Roller Coaster, Project Officers Report, Project 2.6b. Nuclear track autoradiography was performed on the sample from stake 822. Results from this single sample cannot be conclusive.

3.2.3 Air Samples

Fifty-nine air samples were taken for Clean Slate I. Table 3.2 summarizes the highest concentrations. Lathrop Wells experienced the highest airborne activity at a population center. The highest off-site concentration was observed at Stake 108 on Highway 95. Complete air sample results for both gross alpha counts and filters selected for radiochemistry and uranium fluorimetry are in Appendix D.

3.3 CLEAN SLATE II

3.3.1 Ground Monitoring

No plutonium contamination was detectable off the test range complex following this event. Alpha emitting isotopes were detected from Stakes 829 to 847, approximately 22 miles south to southeast of ground zero. A maximum indication of 1200 dpm/ft^2 on a survey meter was obtained at Stake 835.

Readings taken from Stakes 903 to 919, almost due south of ground zero, showed alpha emitters present with a maximum of 900 dpm/ft^2 at Stakes 907. The area from Cedar Pass to east and north of ground zero was monitored, with no indications above background. Monitoring activities were suspended due to heavy rains in the area. Monitoring the following day indicated that no radiation level above normal background could be detected.

3.3.2 Fallout Collectors

Film Collectors

No film collectors from off-site were chosen for analysis; however, nine samples were selected from the on-site collectors in the area of Stakes 840 to 847. The greatest activity was 8520 dpm/ft^2 ^{239,240}Pu at stake 840. Complete film collector results are tabulated in Appendix B.

Glass Slides

Four slides were selected for analysis from the area of highest activity on the test range complex. Phosphor Intensification Autoradiography, however, yielded only 14 total image spots for the four samples.

Results of the special particulate analysis of PHS samples for Clean Slate II can be found in Appendix C and in the Project Officers Report, Project 2.6b.

3.3.3 Air Samples

One hundred and nine air samples were taken following Clean Slate II. Four samples showing activity above background from gross alpha counting were submitted for radiochemical analysis. Table 3.3 shows these results. All samples above background were from the test range complex. Complete air sample results are in Appendix D.

3.4 CLEAN SLATE III

3.4.1 Ground Monitoring

Highway 95 was monitored from Scotty's Junction south to Beatty. Roads across the test range complex, south of ground zero, were also covered. No readings above background were observed. Heavy rains in the area washed into the soil any small quantities of contamination that might have been present. Appendix A shows the monitoring locations.

3.4.2 Fallout Collectors

Film Collectors

Like Clean Slate II, this event was an explosion inside a storage structure, and almost no contamination was found at significant distances. Only five film collectors were analyzed following Clean Slate III. Table 3.4 summarizes these data. None of the samples indicated high activity, but those on the test range complex (801, 848, and 901) showed the most activity. Stakes 100 and 120 are in the vicinity of Springdale and Beatty, respectively.

3.4.3 Air Samples

One hundred and twenty-nine air samples were taken for Clean Slate III, with only two showing significant activity. Stakes 838 and 848, on the test range complex, showed 1.64×10^{-13} μCi/cc and 1.45×10^{-12} μCi/cc, respectively. A complete listing of air samples taken is in Appendix D.

TABLE 3.1 POPULATED LOCATIONS WITH THE HIGHEST PLUTONIUM-239, 240 AIR CONCENTRATIONS FOLLOWING DOUBLE TRACKS

Location	PHS Sample No.	Sampling Period	Total air volume of sample-M^3	$^{239,240}Pu$ Air concentration μCi/ml
Beatty, Nev.	05	1245-5/14 1300-5/15	2989	5.22×10^{-12}
Beatty, Nev.	06	1300-5/15 1320-5/16	3102	1.38×10^{-13}
Death Valley Jct., California	07	1630-5/14 1630-5/15	2570	1.15×10^{-12}
Death Valley Jct., California	08	1630-5/15 1920-5/16	2570	2.33×10^{-13}
Lida Junction, Nevada	22	1920-5/14 0718-5/15	1428	2.83×10^{-12}
Lida Junction, Nevada	23	0722-5/15 1400-5/15	789	2.57×10^{-14}
Scotty's Junction, Nevada	25	0830-5/14 (1) -5/15	2200	5×10^{-12}
Scotty's Junction, Nevada	26	0830-5/15 0830-5/16	2630	3.70×10^{-13}
Asphalt Batch Plant (stk 76)	46	2100-5/14 1157-5/15	1280	1.29×10^{-11}
Asphalt Batch Plant (stk 76)	47	1112-5/15 0254-5/16	1470	2.59×10^{-13}

(1) Sampler malfunctioned; sampling volume estimated.

TABLE 3.2 POPULATED LOCATIONS WITH THE HIGHEST PLUTONIUM-239, 240 AIR CONCENTRATIONS FOLLOWING CLEAN SLATE I

Location	PHS Sample No.	Sampling Period	Total air volume of sample-M^3	$^{239,240}Pu$ Air concentration µCi/ml
Alamo, Nev.	04	0630-5/25 0600-5/26	2305	3.92×10^{-14}
Lathrop Wells, Nevada	19	0625-5/26 0630-5/27	2387	1.41×10^{-13}
Lathrop Wells, Nevada	20	0635-5/27 0615-5/28	2422	1.49×10^{-14}
Lund, Nevada	24	0640-5/26 0800-5/27	2799	2.07×10^{-14}
Stake 108	48	0130-5/25 0930-5/25	782	8.55×10^{-14}
Stake 108	49	1000-5/25 0200-5/26	1237	2.21×10^{-14}

TABLE 3.3 LOCATIONS WITH THE HIGHEST PLUTONIUM-239, 240 AIR CONCENTRATIONS FOLLOWING CLEAN SLATE II

Location	PHS Sample No.	Sampling Period	Total air volume of sample-M^3	$^{239,240}Pu$ Air concentration µCi/ml
Stake 824	65	1720-5/30 1330-5/31	1735	7.11×10^{-14}
Stake 832	68	1655-5/30 1330-5/31	1599	1.21×10^{-13}
Stake 838	71	1630-5/30 1000-5/31	1904	1.10×10^{-13}
Stake 848	74	1600-5/30 0954-5/31	1582	1.13×10^{-14}

TABLE 3.4 FILM COLLECTORS, CLEAN SLATE III

Location	Tracerlab sample no.	$^{239,240}Pu$ dpm/ft^2	Data Reported By
Stake 100	10075	47.8 $\pm$ 1.5	Isotopes, Inc.
Stake 120	10076	33.3 $\pm$ 1.4	Isotopes, Inc.
Stake 801*	10068	393 $\pm$ 9	Isotopes, Inc.
Stake 848*	10069	380 $\pm$ 9	Isotopes, Inc.
Stake 901*	10064	201 $\pm$ 5	Isotopes, Inc.

* on-site

CHAPTER 4
DISCUSSION

Both Clean Slate II and Clean Slate III contributed very little alpha activity to areas beyond the test range complex. Double Tracks released the most activity.

4.1 GROUND MONITORING AND FILM COLLECTORS

Ground monitoring was used strictly to delineate the boundaries, to give an idea of the relative quantities of alpha emitter deposition,and to supply time of arrival of the cloud. Other sample analyses are used to more closely relate any potential health hazard. Deposition samples can corroborate the relative results.

All monitoring results off-site following Double Tracks were less than 100 dpm on the survey instruments. Using the conversions by NRDL, concentrations were less than $0.2 \mu g/M^2$. Higher readings on the test range complex from Stake 259 to Stake 262 indicated the direction of cloud travel to off-site locations. By the time the Double Tracks effluent reached Highway 95, it had diluted greatly and smeared generally from Goldfield to Beatty.

Ground monitoring after Clean Slate I on the test range complex showed activity east and southeast of ground zero.

Survey instruments indicated significant activity just off-site on the road between Reed and Diablo. The previous conversion table yields an approximation between one and two $\mu g/M^2$ at this location. A review of the results shows this to be a hot spot in the off-site survey.

Detailed discussions of film collector results are contained in other project reports. Computer programs have been written to determine microgram quantities from arrays of film collectors. Detailed discussion of the significance in relation to other types of samples will be one of the main points of the project results.

By choosing the ground monitoring readings above 100 dpm (survey meter, sensing area of about 60 cm^2) and comparing them to results of radiochemical analysis, the information in Table 4. 1 is obtained.

The comparison of ground monitoring to film collector radiochemistry for Clean Slate I is summarized in Table 4. 2. Rain may have had some effect in producing ratios <1.0. Observers at the scene felt that some of the film collector deposit may have been washed from the surface in spite of the adhesive. Any excessive moisture on the ground would make the ground monitoring figures low due to shielding of the alpha particles and due to leaching of the contaminant.

An average of the results, excluding the high and low values because of the above conditions, from Double Tracks and Clean Slate I yields a collector to ground monitoring ratio of 1.6. Another report of Operation Roller Coaster will compare various methods of detecting and quantitating surface deposition. In the following section a comparison will be made between air sample results and surface deposition quantities.

Chapter 3 discussed the relative boundaries of contaminated areas using film collector information. It is not possible here to report film collector results in terms of $\mu gm/M^2$ due to the paucity of specific isotope information. For example, the results of radiochemistry are reported as $^{239,240}Pu$ because of the similarity of the alpha particle energies between these isotopes. The presence of uranium does not simplify the analysis. Computer programs to account for these parameters and others have been written in another program of the project. Fortunately, a valid health evaluation can be made in terms of alpha activity.

4.2 AIR SAMPLING AND FILM COLLECTORS

Air sample information tabulated in Chapter 3 and in Appendix D showed that short term air concentrations at a number of locations were above the MPC(maximum permissible concentration) for individuals in the off-site population (AEC Manual Chapter 0524). The MPC's are $6x10^{-14}$ and 10^{-12} μCi/cc for soluble and insoluble $^{239,240}Pu$ respectively. These guides are based on continuous exposure for a lifetime and are usually applied to yearly averages. Thus, although a number of results from Tables 3.1, 3.2, and 3.3 were up to several hundred times the soluble MPC, if it is assumed that other significant similar exposures (bone or lung as critical organ) did not occur in this area during the year, then the guides were not exceeded. The highest air concentration existed at Stake 76 (32 miles NW of Beatty) where a highway construction crew was working at an Asphalt Batch Plant. The cloud arrived between 0500 and 0600 hours when the crew was probably present. The concentration was greater than 10 times the soluble MPC or 200 times the insoluble MPC for a period of less than one day (averaged over the period from 2100 on the day prior to the detonation to 1157 on the day of the event).

Five other locations had transient concentrations above MPC: Beatty, Nevada; Death Valley Junction, California; Scotty's Junction, Nevada; Lathrop Wells and Lida Junction, Nevada. Section 4.3 contains further discussion of doses. The air sample results for successive events did not show levels significantly above background, nor were there any other instances of plutonium contamination during the year. The levels averaged over the year do not exceed the stated limits.

An interesting factor can be obtained by comparing fallout collector information to integrated air sample activity at the same location and over the same period of time. The ratio which defines a parameter termed deposition velocity is:

$$V_d = \frac{\text{ground contamination/unit area}}{\text{time integral air concentration}}$$

The time integral air concentration (air concentration times the length of sampling period) is an expression representing the entire contamination cloud passing over the film collectors. The units used here are:

$$V_d = \frac{\mu Ci/cm^2}{\mu Ci\text{-}sec/cm^3} = cm/sec.$$

Based on 14 locations where results for air samplers and fallout collectors were available, an average V_d of about 2.4 cm/sec was calculated; the values ranged from 0.4 to 7.4 cm/sec. The comparison is on the basis of activity in µCi rather than the mass of the plutonium particulate.

4.3 RELATION TO THE BIOLOGICAL HAZARD

The major radiological hazard in the accidental, non-nuclear detonation of a plutonium-bearing weapon will be the inhalation of the airborne fine particulate debris. Plutonium dioxide particles will more often exist as portions of larger particles of materials found in the particular environment. These composite particles which present the inhalation problem are generally considered to be less than 10µ in diameter (predominantly 1 - 3µ); larger particulates are not respirable, i.e. capable of remaining airborne in order to reach the lung passages. Due to the distance the aerosal cloud traveled to reach the off-site areas from the Roller Coaster detonations, it is reasonable to assume that the larger particles had fallen out. The limited data from the special particulate studies tend to corroborate this point.

The International Commission on Radiation Protection (ICRP) considered the characteristics of industrial dust in the development of a specific lung model.[5] In this model, 25 percent of the particles inhaled are exhaled without internal deposition; 50 percent of the particles are deposited in the upper respiratory passages and eventually eliminated through endocytosis and ciliary and mucus transport out of the lungs to the gastrointestinal tract.

The remaining 25 percent are considered to be deposited in the lower respiratory passages. At this point, distinction is made between soluble and insoluble forms of the radionuclide. Plutonium dioxide is not considered readily soluble, so half of that in the lower respiratory passages (12.5 percent) is eliminated within 24 hours through the upper respiratory area to the G. I. tract,and the remaining fraction is retained in the lungs with a one year biological half-life. This latter portion is assumed to be taken into the body fluids. This model, with other necessary biological factors, was used in the determination of the maximum permissible concentration, in air, and is also the basis for the permissible levels given in Chapter 0524 of the AEC Manual.

This is, perhaps, a good gross model in predicting the deposition paths and the physiological clearance mechanisms, especially considering the great variation of conditions encountered in any given plutonium inhalation situation.

In a report submitted to Committee II of the ICRP in April 1965, a more detailed lung model was presented.[16]

The inhaled particles in this model are separated into four deposition compartments. One component consists of the particles which remain airborne in the tidal volume and are exhaled without any internal deposition. The second compartment, the nasal-pharynx, includes the earliest deposition sites from the nose down to the larynx or epiglottis. The tracheobronchial compartment corresponds essentially to the earlier upper respiratory designation and extends to the terminal bronchioles. The lowest site of respiratory deposition was entitled pulmonary and encompasses the functional exchange area of the lungs. Another distinction of this fourth compartment is the lack of ciliary-mucus clearance ability that is present in the tracheobronchial region. Further discussion of the theory of this model is given in Reference 16.

The highest off-site air concentration during Operation Roller Coaster occurred at the Asphalt Batch Plant (Stake 76, see Table 3.1). Workers were present at the time of cloud passage. The following is an attempt to calculate the limiting potential dose for this location, using the new ICRP model.

When definite knowledge of the particle size is not known, the ICRP task force recommended use of a mass or activity median aerodynamic diameter (AMAD) of 1μ.[16] Because of the high density of the material of concern (10 for this event according to Church[23]), an activity median diameter of 1μ was used which then converts to an AMAD of 3.2μ. This results in a fairly conservative particle size distribution, i.e. a change in size of ±2μ would not significantly change the results.[16]

Biological uptake and clearance constants for inhalation of material with an AMAD of 3.2μ are given in Table 4.3. These parameters, taken from Reference 16, are for avid or long term retention. It is assumed that the inhaled material is essentially insoluble and the lung is the critical organ.[5]

From Table 3.1 it can be calculated that the integrated $^{239,240}Pu$ air concentration at the Asphalt Batch Plant (Stake 76) was 7×10^{-7} μCi-sec/cm^3. Based on a breathing rate of 3.48×10^{-4} M^3/sec,[5] which corresponds to that of a working man, and the uptake parameters in Table 4.3, the potential uptake quantities in Table 4.4 can be calculated.

From Tables 4.3 and 4.4 it can be seen, based on retention time and percent deposition, that the pulmonary section of the lung receives the greatest dose. Several problems occur in attempting to calculate the dose including the uniformity of distribution of plutonium in the pulmonary compartment and depth dose. These problems may be bypassed, as is usually done, by averaging the dose over the mass of the pulmonary tissue. The intent is not to imply that this procedure is correct and that high localized doses have the same effect as average doses but rather this technique is necessary because of limited knowledge. Thus, using the ICRP[5] value for $\sum E(RBE)n$ of 53 Mev(RBE) (assumes RBE of 10) and a tissue mass of 700 grams for the pulmonary compartment, the dose to the pulmonary section of the lung is (the factor in brackets results from integrating the dose rate over time):

$$\frac{0.61 \times 10^{-4} \mu Ci}{\text{Pulmonary sec}} \times \frac{\text{Pulmonary Section}}{700 \text{ grams}} \times \frac{3.7 \times 10^{4} \text{ dis/sec}}{\mu Ci} \times \frac{53 \text{ Mev(RBE)}}{\text{dis}} \times$$

$$\frac{1.602 \times 10^{-6} \text{ ergs}}{\text{Mev}} \times \frac{\text{Rad}}{100 \text{ ergs/gram}} \times (1-\exp-.693 \times 360/360) \times \frac{360 \text{ day}}{0.693} \times$$

$$\frac{8.64 \times 10^{4} \text{ sec}}{\text{day}} = 6.1 \times 10^{-2} \text{ rad}$$

Since the RBE was included in the Mev the dose is actually in rem. Thus, the potential dose to the pulmonary section of the lung for men at the Asphalt Plant was about 60 millirem for the first year after exposure and 120 millirem for the infinite dose based on the previous model and assumptions. It is emphasized that this dose was not actually measured by whole body counting but is rather a math model estimate of the potential dose to the pulmonary section of the lung which was the critical organ (based on the assumption of the insoluble nature of the plutonium material). These doses are below the guidelines of the AEC Manual Chapter 0524.

The probability of uneven distribution within defined deposition compartments remains a problem. Health physics evaluation would only have consequence, in this aspect, with exposures through very high concentrations of the type expected in an accident situation. Attempts at mapping the deposition might be possible through whole body counting techniques. Assessment of plutonium deposition with large volume proportional counters has been attempted successfully by several[19,20] as have thin film scintillators.[21] It might be feasible to

construct an array of thin film scintillators with independent photomultiplier tubes to provide some better definition of internal deposition sites with some quantitative representation. This application would be very specific and probably only of benefit in the most severe contamination incidents.

TABLE 4.1 COMPARISON OF GROUND MONITORING TO RADIOCHEMICAL ANALYSIS OF DOUBLE TRACKS FILM COLLECTORS

Location (on-site)	Ground monitoring results dpm/ft^2	Time of ground monitoring	Film collector results dpm ^{239,240}Pu/ft^2	Ratio of film collector to ground monitoring
Stake 257	9,300	1200	7,030	0.76*
258	2,015	1155	13,900	6.9
259	31,000	1430	56,100	1.8
260	31,000	1500	43,100	1.4
261	31,000	1230	51,100	1.6
262	31,000	1205	43,100	1.4

* = There are several possible explanations for the scatter in the ratios for Stakes 257 and 258. Possible causes of unusual ground monitoring results could be monitor error in survey meter readings, faulty survey meters, contaminated survey meters, etc. Differences could occur in film collector results from cross-contamination (or conversely loss of activity) during sample handling, weathering, etc.

TABLE 4.2 COMPARISON OF GROUND MONITORING TO RADIOCHEMICAL ANALYSIS OF CLEAN SLATE I FILM COLLECTORS

Location	Ground monitoring results dpm/ft^2	Time of ground monitoring	Film collector results dpm $^{239,240}Pu/ft^2$	Ratio of film collector to ground monitoring
Stake 816	10,850	1145	17,700	1.6
	Bkgd	1333		---
817	21,700	1153	10,500	0.48
	7,750	1337		1.4
818	15,500	1202	31,200	2.0
	10,850	1342		2.9
819	23,250	1208	37,700	1.6
	10,850	1346		3.5
820	23,250	1222	48,000	2.1
	9,300	1345		5.2
821	10,850	1225	15,500	1.4
	15,500	1400		1.0
822	23,250	1237	1,260	0.05
	10,850	1356		0.12
823	12,400	1410	11,000	0.89
824	18,600	1252	3,700	0.20
	3,000	1410		1.2

Note: Possible causes of unusual ground monitoring results could be monitor error in survey meter readings, faulty survey meters, contaminated survey meters, etc. Differences could occur in film collector results from cross-contamination (or conversely loss of activity) during sample handling, weathering, etc.

TABLE 4.3 PARAMETERS FOR USE WITH CLEARANCE MODEL[16]

Compartment	Percent* Deposited	Clearance Path	Clearance Half-time	Fraction of Compartment Following the Path
Nasal-pharyngeal	60	Absorbed into blood	4 min	0.01
		Ciliary-mucus to G I tract	4 min	0.99
Tracheobronchial	5	Absorbed into blood	10 min	0.01
		Ciliary-mucus to G I tract	10 min	0.99
Pulmonary	25	Absorbed into blood	360 da	0.05
		Fast transport to G I tract	24 hr	0.40
		Slow transport to G I tract	360 da	0.40
		Absorption into Lymph	360 da	0.15
Exhaled	10	---	---	---
Lymph		Lymph to blood**	360 da	0.10

** Remaining 90% from pulmonary absorption is retained permanently in lymph nodes.

* Values for a geometric standard deviation of about 2(may vary by up to 20% for other deviations) and a tidal volume of 1450 ml.

TABLE 4.4 POTENTIAL UPTAKE

Compartment	μCi Deposited
Inhaled	2.44×10^{-4}
Exhaled	0.24×10^{-4}
Nasal-pharyngeal	1.46×10^{-4}
Tracheobronchial	0.12×10^{-4}
Pulmonary	0.61×10^{-4}

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 OFF-SITE RADIOLOGICAL SURVEY

Survey instruments were just able to detect surface concentrations off-site following Double Tracks, while air concentrations were more easily detected. Except for an isolated hot spot following Clean Slate I, no other ground monitoring results were observed beyond the test range complex.

Of the type of samples taken, air sample data yielded the best and most direct radiological health evaluation. Fallout collectors proved to be more sensitive in defining the area of contamination than survey instrument readings, but information from survey meters is more readily available. Also, survey meter readings can be obtained at locations selected after the fact where fallout collectors must be positioned prior to an event. Fallout collector information with air concentrations at common locations allowed calculation of deposition velocity.

Following Double Tracks, several locations had short-term air concentrations in excess of MPG's(intended for average annual concentrations), but the duration of elevated concentrations was relatively short,and concentrations did not exceed the limits when averaged over the year. Subsequent to all the experiments, many air samples were taken beyond the test range complex with no indication of resuspended activity. The history of alpha emitter exposure to residents in the area is known and is very minimal.

The amount of contamination off-site, following Double Tracks, can provide an element of wisdom in determining the location and size of any future experiments of the same nature. None of the off-site exposures constituted a serious hazard.

5.2 RECOMMENDED EMERGENCY PROCEDURES

A major problem in a plutonium accident is the first determination of the extent of contamination soon enough to allow the most important early measures at the points of concern. The only measures practicable would entail close-in air sampling and survey instrument alpha monitoring. From air sampling results an indication of the hazard at and downwind of the sampling point can be inferred. Final reports of Operation Roller Coaster should allow good determinations of downwind hazards in relation to close in information. If the hazard is limited to an immediate area, the problem reduces itself to keeping people out and controlling the spread of contamination with fixing agents such as water and road oil.

Preliminary reports of the biological experiments show the primary inhalation hazard is at the time of cloud passage. Thus, by the time of arrival of monitors on the scene, major exposure will have already occurred. Yet, in an accident where high levels of contamination are present in the immediate area, one must assume the existence of a resuspension hazard and restrict access pending clean-up action.

Ground monitoring, guided by the best explosion-time meteorological information available, would be used to give the first specific information to delineate areas for contamination control and of possible resuspension hazards. On the scene observance of wind direction as well as information from the U. S. Weather Bureau will give the general direction of cloud travel. The area of most intensive fallout still does not necessarily indicate respirable hazard zone, although the area must be used to determine the general direction of travel of the contamination cloud.

Air sampling should be started as soon as possible. Sampling locations are best chosen on the basis of ground survey results, wind data, and major topographic features. A portable alpha counting capability for air sample analysis should be considered, even though it may only be a calibrated survey instrument with a stand for the probe. High volume air samplers should be used to sufficiently concentrate activity on the filter to allow rapid determinations. At the same time, annular or cascade impactors should be used to estimate particle size so eventual determination could be made of pulmonary deposition at specific locations. The value of fallout collectors would be very dubious particularly due to the time required for their placement. It would probably be better to choose some undisturbed ground surfaces for monitoring for a measurement of surface contamination. Soil samples could be submitted for radiochemistry should more accurate determinations be required later. In the worst case, hazardous concentrations in a populated area could reach sufficient severity to require evacuation. This would involve a relatively small area and would probably be necessary only in the event of a transportation accident due to existing offset distances required for storage. Local, state, and federal health personnel should be used. The exact threshold for a hazardous concentration sould have to be determined by responsible individuals at the scene.

In the time required for assembly of emergency personnel and for the decisions to be made, any close-in population will have received the major inhalation dose due to cloud passage. Thought should be given to people farther downwind; they might be moved before maximum cloud levels arrive. Should a situation this critical arise, use of dry handkerchief, tissue, or cloth should not be overlooked as a deterrent to further respiratory intake. The people close-in should be considered for contamination control, removed from any area where a resuspension hazard could exist, and given medical treatment. Fecal and urine analysis of any heavily exposed people is necessary to evaluate the amount taken up. The majority of close-in activity will consist primarily of larger particle sizes—a lesser inhalation hazard in comparison to total activity observed, characterized by high activity in fecal samples. The presence of larger particle size activity close-in could be a prime factor in determining what evacuation might be necessary.

Any medical treatment to help reduce the final dose received by exposed people will have to be initiated immediately. A good outline of several possible procedures is in the Safety Manual of the University of Utah's Radiobiology Division of the College of Medicine. Procedures here include such things as the use of DTPA as a chelating agent to prevent skeletal deposition and stopping the exposed person from smoking to allow better ciliary clearance. Other chelating agents have shown successful dose reduction. Unfortunately, the time frame might not allow effective measures. Experts at Los Alamos Scientific Laboratory and at Hanford Atomic Products Operation have had significant experience in the use of chelating agents.

5.3 RECOMMENDATIONS FOR FUTURE EXPERIMENTS

A detonation similar to that of Double Tracks could be tolerated by the populace surrounding the test range complex. Some other site would have to be chosen with an experiment expected to yield significantly more contamination or if more shots were conducted. Experiments such as the Clean Slate shots could very readily be accommodated, keeping in mind there was some reduction of contamination levels due to rainfall.

The procedures used by the Public Health Service were sufficient to observe and evaluate the radiological situation off-site. Certain analyses were performed on PHS samples which were not used to evaluate the off-site picture, but they will be used to complete other programs of the Project. The procedure of sorting air samples by gross alpha count and then submitting samples showing activity for radiochemistry proved convenient. The use of film collectors showed relative quantities of contamination, and in conjunction with air samples, provided information to determine fallout rate. Ground monitoring showed only the areas of highest activity but did indicate the fallout time required before readings became observable.

More investigation should be made in any future experiment for special particulate analysis to determine particle size and form for off-site samples. Conscientious effort should also be made to select fallout collectors and air samples from the same locations to allow correlation. Air samples should be taken with an annular or cascade impactor to show more conclusively the respirability of the cloud at greater distances from ground zero. Many more samples should be taken to effectively describe any hazard. All of these things were effected as part of Roller Coaster but not consistently with off-site samples.

The methods of analysis employed and the overall administration and correlation of all the various projects were excellent. A wealth of valuable information can be applied to a hazard which is rarely presented but potentially so great that it must be well understood.

APPENDIX A SUMMARY OF GROUND MONITORING

GROUND MONITORING RESULTS
ROLLER COASTER
Double Tracks
May 15, 1963

Time	Location	Disintegrations per Minute (Gross)	Time	Location	Disintegrations per Minute (Gross)
0548	Stake 15	18	0840	Stake 51	BKG
0600	Stake 15A	16	0910	Stake 51	40
0605	Stake 16A	4.2	1000	Stake 53	54
0609	Stake 16A	14	1005	Stake 54	18
0612	Stake 17	8	1010	Stake 55	74*
0621	Stake 18	18	1010	Stake 56	14
0625	Stake 18A	7.8	1015	Stake 57	80*
0630	Stake 19	16	1015	Stake 58	10
0635	Stake 19A	18	1020	Stake 59	270*
0800	Stake 21	40	1020	Stake 60	20
0740	Stake 23	BKG	1035	Stake 61	300*
0810	Stake 23	48	1025	Stake 62	20
0745	Stake 25	BKG	1040	Stake 63	300*
0815	Stake 25	48	1030	Stake 64	30
0750	Stake 27	BKG	1045	Stake 65	300*
0820	Stake 27	40	1034	Stake 66	30
0755	Stake 29	BKG	1050	Stake 67	24
0830	Stake 29	50	1039	Stake 68	20
0800	Stake 31	BKG	1100	Stake 69	44
0845	Stake 31	40	1048	Stake 70	40
0838	Stake 33	10	1120	Stake 71	24
0805	Stake 35	BKG	1125	Stake 73	50
0850	Stake 35	40	1130	Stake 75	28
0843	Stake 37	10	1056	Stake 76	30
0810	Stake 37	BKG	1135	Stake 77	24
0815	Stake 39	BKG	1115	Stake 78	40
0850	Stake 39	40	1140	Stake 79	30
0849	Stake 41	10	1120	Stake 80	30
0820	Stake 41	BKG	1145	Stake 81	28
0900	Stake 43	40	1135	Stake 82	14
0825	Stake 45	BKG	1150	Stake 83	20
0855	Stake 45	10	1140	Stake 84	10
0830	Stake 47	BKG	1155	Stake 85	24
0905	Stake 47	40	1145	Stake 86	20
0835	Stake 49	BKG	1202	Stake 87	18
0900	Stake 49	10	1150	Stake 88	16
0710	Stake 50	16	1205	Stake 89	30

*Taken with malfunctioning instrument. Instrument replaced and continued readings were background.

Ground Monitoring Results, Roller Coaster, Double Tracks, May 15, 1963

Time	Location	Disintegrations per Minute (Gross)	Time	Location	Disintegrations per Minute (Gross)
1155	Stake 90	16	1200	Stake 257	600
1210	Stake 90A	36	1155	Stake 258	130
1215	Stake 91	32	1217	Stake 259	1150
1205	Stake 92	20	1255	Stake 259	1500
1220	Stake 93	30	1430	Stake 259	2000
1212	Stake 94	18	1200	Stake 260	180
1225	Stake 95	28	1245	Stake 260	800
1218	Stake 96	20	1500	Stake 260	2000
1230	Stake 97	18	1230	Stake 261	2000
1220	Stake 98	18	1445	Stake 261	2000
1235	Stake 99	18	1205	Stake 262	2000
1225	Stake 100	10	1520	Stake 262	1200
1240	Stake 101	34	1305	Stake 262	1000
1230	Stake 102	10	0710	Stake 301	40
1245	Stake 103	30	0715	Stake 302	68
0855	Stake 202	14	0723	Stake 303	40
0903	Stake 206	22	0730	Stake 304	44
0920	Stake 210	32	0735	Stake 305	48
0930	Stake 214	36	0800	Stake 306	10
0940	Stake 218	18	0806	Stake 307	10
0950	Stake 222	32	0812	Stake 308	10
1000	Stake 223	26	0554	Stake 601	10
1010	Stake 225	20	0552	Stake 602	10
1015	Stake 227	16	0558	Stake 603	10
1020	Stake 229	24	0602	Stake 604	10
1025	Stake 231	30	0607	Stake 605	14
1030	Stake 233	32	0615	Stake 606	14
1035	Stake 235	28	0647	In Route	14
1042	Stake 237	38	0657	Stake 607	14
1050	Stake 239	22	0626	Ralston Junction	100
1106	Stake 241	16	0626-	Ralston Junction to	
1111	Stake 243	22	0758	4 mi SE (10 rdgs)	100
1119	Stake 245	20	0805	No. 5 Barricade	100
1125	Stake 247	50	0814	South toward	
1130	Stake 249	44		Stonewall Spgs.	100
1138	Stake 251	42	0814-	No. 5 Barricade S	
1145	Stake 253	26	0918	to Stonewall Spgs.	
1140	Stake 254	56		(4 readings)	100
1155	Stake 255	22	0918	Stonewall Spgs.	300
1145	Stake 256	56	0600-	Lida Junction	
			0755	(6 readings)	48
			0805	Scotty's Junction	20

GROUND MONITORING RESULTS
ROLLER COASTER
Clean Slate I
May 25, 1963

Time	Location	Disintegrations per Minute Net	Gross	Time	Location	Disintegrations per Minute Net	Gross
0910	Stake 54	BKG		0955	Stake 207	BKG	
0910	Stake 55	BKG		1000	Stake 209	BKG	
0915	Stake 56	BKG		1000	Stake 211	BKG	
1015	Stake 57	BKG		1005	Stake 213	BKG	
1020	Stake 58	BKG		1015	Stake 215	BKG	
1025	Stake 69	BKG		1020	Stake 217	BKG	
1025	Stake 76(Asphalt			1025	Stake 219	BKG	
	Batch Plant)	BKG		1030	Stake 221	BKG	
1300	Stake 86	BKG		1030	Stake 222	BKG	
1255	Stake 87	BKG		1035	Stake 223	BKG	
1244	Stake 88	BKG		1038	Stake 224	BKG	
1239	Stake 89	BKG		1040	Stake 225	BKG	
1234	Stake 90	BKG		1045	Stake 226	BKG	
1229	Stake 90A	BKG		1045	Stake 227	BKG	
1224	Stake 91	BKG		1050	Stake 228	BKG	
1219	Stake 92	BKG		1050	Stake 229	BKG	
1215	Stake 93	BKG		1055	Stake 230	BKG	
1209	Stake 94	BKG		1055	Stake 231	BKG	
1204	Stake 95	BKG		1100	Stake 232	BKG	
1158	Stake 96	BKG		1100	Stake 233	BKG	
1151	Stake 97	BKG		1105	Stake 234	BKG	
1143	Stake 98	BKG		1105	Stake 235	BKG	
1139	Stake 99	BKG		1110	Stake 236	BKG	
1135	Stake 100	BKG		1115	Stake 237	BKG	
1128	Stake 101	BKG		1120	Stake 238	BKG	
1124	Stake 102	BKG		1120	Stake 239	BKG	
1121	Stake 103	BKG		1125	Stake 240	BKG	
1117	Stake 104	BKG		1000	Stake 435	BKG	
1106	Stake 105	BKG		1030	Stake 436	BKG	
1112	Stake 106	BKG		1040	Stake 439	BKG	
1100	Stake 107	BKG		1045	Stake 443	BKG	
1005	Stake 108	BKG		1055	Stake 447	BKG	
0940	Stake 201	BKG		1230	Stake 801	BKG	
0945	Stake 203	BKG		1235	Stake 802	BKG	
0948	Stake 205	BKG		1240	Stake 803	BKG	

Ground Monitoring Results, Roller Coaster, Clean Slate I, May 25, 1963

Time	Location	Disintegrations per Minute Net	Gross	Time	Location	Disintegrations per Minute Net	Gross
1245	Stake 804	BKG		1440	Stake 829	BKG	
1250	Stake 805	BKG		1440	Stake 830	BKG	
1255	Stake 806	BKG		1450	Stake 831	BKG	
1300	Stake 807	BKG		1255	Stake 832	BKG	
1305	Stake 808	BKG		1310	Stake 834	BKG	
1308	Stake 809	BKG		1320	Stake 836	BKG	
1310	Stake 810	BKG		1325	Stake 838*	BKG	
1314	Stake 811	BKG		1330	Stake 838*	BKG	
1318	Stake 812	BKG		1335	Stake 840	BKG	
1322	Stake 813	BKG		1340	Stake 842	BKG	
1325	Stake 814	BKG		1332	Stake 843	BKG	
1330	Stake 815	BKG		1345	Stake 844	BKG	
1333	Stake 815	BKG		1350	Stake 846	BKG	
1145	Stake 816*		700	1400	Stake 848	BKG	
1145	Stake 816*		700	1605	Stake 902	BKG	
1153	Stake 817*		1400	1602	Stake 903	BKG	
1337	Stake 817*		400-	1560	Stake 904	BKG	
			600	1555	Stake 905	BKG	
1202	Stake 818*		1000	1550	Stake 905A	BKG	
1342	Stake 818*		700	1208	Stake 906	BKG	
1208	Stake 819*		1500	1214	Stake 907	BKG	
1346	Stake 819*		400-	1220	Stake 908	BKG	
			1000	1225	Stake 909	BKG	
1222	Stake 820*		1500	1229	Stake 910	BKG	
1345	Stake 820*		600	1234	Stake 910A	BKG	
1225	Stake 821*		700	1240	Stake 911	BKG	
1400	Stake 821*		1000	1245	Stake 912	BKG	
1237	Stake 822*		1500	1250	Stake 913	BKG	
1356	Stake 822*		400-	1255	Stake 914	BKG	
			1000	1300	Stake 915	BKG	
1410	Stake 823		800	1305	Stake 916	BKG	
1252	Stake 824		1200	1320	Stake 917	BKG	
1410	Stake 824		200	1325	Stake 918	BKG	
1420	Stake 825	BKG		1330	Stake 919	BKG	
1420	Stake 826	BKG		1335	Stake 920	BKG	
1430	Stake 827	BKG		1340	Stake 921	BKG	
1240	Stake 828	BKG		1100	Warm Spgs.	BKG	
1430	Stake 828	BKG		1120	2 mi SW on		
1440	Stake 829	BKG			Hwy 25**	BKG	

*Readings were taken using different instruments.
**Measured from Warm Springs.

Ground Monitoring Results, Roller Coaster, Clean Slate I, May 25, 1963

Time	Location	Disintegrations per Minute Net	Disintegrations per Minute Gross
1120	5 mi SW on Hwy 25**	BKG	
1130	8 mi SW on Hwy 25**	BKG	
1150	11 mi SW on Hwy 25**	BKG	
1145	14 mi SW on Hwy 25**	BKG	
1205	20 mi SW on Hwy 25**	BKG	
1210	23 mi SW on Hwy 25**	BKG	
1220	Diablo	BKG	
1225	Diablo	BKG	
1228	Diablo to Reed	BKG	
1230	Diablo to Reed	BKG	
1310	Reed*	BKG	
1310	Reed*	BKG	
1315	Reed	BKG	
1535	Reed to Diablo	BKG	
1600	Diablo	BKG	
1320	Reed to Cedar Pass	BKG	
1325	Reed to Cedar Pass	BKG	
1350	West Slope, Cedar Pass		1000-1550
1400	West Slope, Cedar Pass		1000
1405	West Slope, Cedar Pass		800
1410	West Slope, Cedar Pass		800
1420	1 mi W Cedar Pass		800
1435	Barricade on W slope and turn around		700
1450	3 mi E of Barricade		1000
1455	Cedar Pass Summit		1200
1505	Cedar Pass Summit		700
1510	1 mi E Cedar Pass Summit		750
1525	4 mi E Cedar Pass Summit		650
1540	Reed	BKG	
1550	Reed to Diablo		1200
1605	Diablo	BKG	

*Readings were taken using different instruments.
**Measured from Warm Springs.

GROUND MONITORING RESULTS
ROLLER COASTER
Clean Slate II
May 31 through June 1, 1963

Time	Location	Disintegrations per Minute Net	Disintegrations per Minute Gross
May 31			
1100	Stake 224	BKG	
1120	Stake 229	BKG	
1140	Stake 239	BKG	
1145	Stake 240	BKG	
1220	Stake 802	BKG	
1230	Stake 804	BKG	
1245	Stake 812	BKG	
1255	Stake 814	BKG	
1350	Stake 829		200
1400	Stake 832		300
1410	Stake 835		1200
1425	Stake 840		1000
1435	Stake 845		200
1440	Stake 847		200
1540	Stake 848	BKG	
1210	Stake 903	BKG	
1700	Stake 903	BKG	
1650	Stake 906		350
1630	Stake 907		900
1240	Stake 913	BKG	
1545	Stake 915		700
1400	Stake 919		800
1140	Warm Spgs.	BKG	
1150	Twin Spgs.	BKG	
1210	Diablo	BKG	
1235	Reed	BKG	
1310	Cedar Pass Summit	BKG	
1325	2-1/2 mi W of Cedar Pass Summit	BKG	
1345	Wild Horse Ranch	BKG	
1400	2-1/2 mi S of Wild Horse Ranch	BKG	
1410	5 mi S of Wild Horse Ranch	BKG	
1425	7 mi S of Wild Horse Ranch	BKG	
1435	2 mi W of Wild Horse Ranch	BKG	
1450	4-1/2 mi W of Wild Horse Ranch	BKG	
	5 mi S of Wild Horse Ranch	BKG	
June 1			
1245	Stake 76	BKG	
1300	Stake 80	BKG	
1315	Stake 84	BKG	
1325	Stake 88	BKG	
1338	Stake 91	BKG	
1355	Stake 95	BKG	
1410	Stake 99	BKG	
1420	Stake 103	BKG	
1438	Stake 107	BKG	
1450	Stake 111	BKG	
1500	Stake 115	BKG	
1515	Stake 117	BKG	
1530	Stake 121	BKG	

GROUND REMONITORING RESULTS
ROLLER COASTER
Clean Slate II
June 1, 1963

Time	Location*	Disintegrations per Minute (Net)	Time	Location*	Disintegrations per Minute (Net)
1300	Stake 815	BKG	1530	Stake 901	BKG
1310	Stake 817	BKG	1245	Stake 908	BKG
1315	Stake 819	BKG	1300	Stake 909	BKG
1320	Stake 821	BKG	1310	Stake 910	BKG
1330	Stake 823	BKG	1320	Stake 911	BKG
1335	Stake 825	BKG	1335	Stake 912	BKG
1340	Stake 827	BKG	1400	Stake 914	BKG
1345	Stake 829	BKG	1405	Stake 915	BKG
1355	Stake 831	BKG	1420	Stake 916	BKG
1405	Stake 833	BKG	1430	Stake 917	BKG
1410	Stake 835	BKG	1445	Stake 918	BKG
1415	Stake 837	BKG	1450	Stake 919	BKG
1420	Stake 839	BKG	1500	Stake 920	BKG
1425	Stake 841	BKG	1505	Stake 921	BKG
1430	Stake 843	BKG			

*Heavy rain had fallen in the above areas during the night of May 31 - June 1, resulting in background readings at locations which on the previous day had shown activity.

GROUND MONITORING RESULTS
ROLLER COASTER
Clean Slate III
June 9, 1963

Time	Location	Disintegrations per Minute (Net)	Time	Location	Disintegrations per Minute (Net)
1000	Stake 69	BKG	1105	Stake 820	BKG
1015	Stake 71	BKG	1110	Stake 822	BKG
1020	Stake 73	BKG	1125	Stake 824	BKG
1025	Stake 75	BKG	1130	Stake 826	BKG
1030	Stake 77	BKG	1135	Stake 828	BKG
1035	Stake 79	BKG	1140	Stake 830	BKG
1040	Stake 81	BKG	1145	Stake 832	BKG
1045	Stake 83	BKG	1155	Stake 834	BKG
1050	Stake 85	BKG	1200	Stake 836	BKG
1055	Stake 87	BKG	1205	Stake 838	BKG
1100	Stake 89	BKG	1210	Stake 840	BKG
1110	Stake 90	BKG	1215	Stake 842	BKG
1115	Stake 92	BKG	1220	Stake 843	BKG
1120	Stake 94	BKG	1225	Stake 844	BKG
1125	Stake 96	BKG	1230	Stake 846	BKG
1130	Stake 98	BKG	1235	Stake 848	BKG
1135	Stake 100	BKG	0955	Stake 901	BKG
1140	Stake 102	BKG	1005	Stake 902	BKG
1200	Stake 104	BKG	1015	Stake 903	BKG
1210	Stake 106	BKG	1020	Stake 905	BKG
1215	Stake 108	BKG	1025	Stake 906	BKG
1220	Stake 110	BKG	1040	Stake 908	BKG
1225	Stake 112	BKG	1045	Stake 910	BKG
1230	Stake 114	BKG	1050	Stake 911	BKG
1235	Stake 115	BKG	1100	Stake 913	BKG
1245	Stake 117	BKG	1110	Stake 914	BKG
1250	Stake 120	BKG	1120	Stake 915	BKG
0910	Stake 240	BKG	1150	Stake 916	BKG
1000	Stake 802	BKG	1205	Stake 917	BKG
1005	Stake 804	BKG	1210	Stake 918	BKG
1010	Stake 806	BKG	1220	Stake 919	BKG
1050	Stake 808	BKG	1230	Stake 920	BKG
1020	Stake 810	BKG	1240	Stake 821	BKG
1025	Stake 812	BKG			
1030	Stake 814	BKG			
1035	Stake 816	BKG			
1050	Stake 818	BKG			

APPENDIX B SUMMARY OF FILM COLLECTORS RADIOCHEMICAL RESULTS

FILM COLLECTOR RESULTS
ROLLER COASTER
Double Tracks
May 15, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported by
10	10012	8.63 ± 1.15	Tracerlab
10A	10012	.92 ± .21	Tracerlab
11	10012	4.63 ± 1.09	Tracerlab
11A	10012	.76 ± .61	Tracerlab
12	10012	1.10 ± .69	Tracerlab
12A	10012	.480 ± .180	Tracerlab
12	10012	1.28 ± 0.04	Tracerlab
12A	10012	.53 ± .16	Tracerlab
13	10012	12.8 ± .04	Tracerlab
13A	10012	0.53 ± 0.16	Tracerlab
14	10012	1.7 ± .3	Tracerlab
14A	10012	.87 ± .18	Tracerlab
15	10012	4.86 ± .30	Tracerlab
16	10013	.92 ± .29	Tracerlab
16A	10013	2.15 ± .19	Tracerlab
17	10013	36.9 ± 1.4	Tracerlab
17A	10013	6.31 ± .42	Tracerlab
18	10013	3.25 ± .23	Tracerlab
18A	10013	16.7 ± .6	Tracerlab
19	10013	26.5 ± 1	Tracerlab
19A	10013	60.9 ± 2.2	Tracerlab
20	10005	17.2 ± 6	Tracerlab
21	10005	151 ± 4	Isotopes, Inc.
23	10005	308 ± 6	Isotopes, Inc.
25	10005	268 ± 5	Isotopes, Inc.
27	10005	399 ± 8	Isotopes, Inc.
29	10005	451 ± 6	Isotopes, Inc.
31	10005	395 ± 7	Isotopes, Inc.
33	10005	278 ± 4	Isotopes, Inc.
35	10005	237 ± 4	Isotopes, Inc.
36	10007	144 ± 5	Tracerlab
38	10007	127 ± 3	Isotopes, Inc.
39	10007	95.9 ± 2.2	Isotopes, Inc.
41	10007	219 ± 2	Isotopes, Inc.
43	10007	460 ± 5	Isotopes, Inc.
45	10007	312 ± 6	Isotopes, Inc.

Film Collector Results, Roller Coaster, Double Tracks, May 15, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported by
47	10007	395 ± 5	Isotopes, Inc.
49	10007	348 ± 7	Isotopes, Inc.
51	10007	4240 ± 60	Isotopes, Inc.
71	10010	7960 ± 250	Tracerlab
72	10010	6490 ± 200	Tracerlab
73	10010	6940 ± 220	Tracerlab
74	10010	5290 ± 170	Tracerlab
75	10010	6600 ± 230	Tracerlab
76	10010	3070 ± 110	Tracerlab
77	10010	3810 ± 130	Tracerlab
78	10010	3670 ± 130	Tracerlab
79	10010	4180 ± 140	Tracerlab
80	10010	4110 ± 140	Tracerlab
81	10010	225 ± 9	Tracerlab
82	10010	295 ± 10	Tracerlab
83	10010	498 ± 13	Tracerlab
84	10010	812 ± 25	Tracerlab
85	10010	1330 ± 40	Tracerlab
86	10010	1320 ± 30	Tracerlab
87	10010	1470 ± 40	Tracerlab
88	1000.88	1286 ± 30	Hazelton
89	1000.89	950.2 ± 41.1	Hazelton
90	1000.90	1046 ± 50	Hazelton
90A	10000.90A	10.90 ± 0.25	Hazelton
91	1000.91	985.9 ± 53.9	Hazelton
92	10000.92	2154 ± 46	Hazelton
93	10000.93	908.9 ± 13.9	Hazelton
94	10000.94	699.9 ± 21.0	Hazelton
95	1000.95	356.0 ± 9.5	Hazelton
96	1000.96	758.9 ± 22.5	Hazelton
97	1000.97	635.5 ± 17.0	Hazelton
98	1000.98	522.8 ± 11.6	Hazelton
99	1000.99	464.1 ± 8.77	Hazelton
100	10000	589.2 ± 21.8	Hazelton
101	1000.101	1315 ± 33	Hazelton
102	10000.102	1544 ± 46	Hazelton
103	10000.103	1672 ± 41	Hazelton
201	010026	640 ± 25	Eberline

Film Collector Results, Roller Coaster, Double Tracks, May 25, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported By
202	010026 010026	193 ± 8 186 ± 13	Eberline
203	010026 010026	103 ± 4 126 ± 11	Eberline
204	010026 010026	17.8 ± 1.2 16 ± 4	Eberline
205	010026 010026	31.4 ± 1.2 36 ± 5	Eberline
206	010026 010026	31.5 ± 1.2 36 ± 6	Eberline
207	010026 010026	107 ± 4 115 ± 10	Eberline
208	010026 010026	25.6 ± 0.8 33 ± 6	Eberline
209	010026 010026	27 ± 1 24 ± 5	Eberline
210	010026 010026	284 ± 7 15 ± 4	Eberline
211	010026 010026	45.9 ± 2 45 ± 6	Eberline
212	010026 010026	51.4 ± 2.1 43 ± 6	Eberline
213	010026 010026	25.9 ± 1.3 22 ± 4	Eberline
214	010026	570 ± 46	Eberline
215	010026 010026	258 ± 5 300 ± 17	Eberline
216	010026 010026	592 ± 17 580 ± 44	Eberline

Film Collector Results, Roller Coaster, Double Tracks, May 25, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported By
217	010026	52 ± 2	Eberline
	010026	50 ± 10	
218	010026	302 ± 7	Eberline
	010026	400 ± 32	
219	010019	8 ± 2	Eberline
	010019	46.2 ± 1.2	
220	010019	209 ± 5	Eberline
	010019	290 ± 20	
221	010019	45.5 ± 1.9	Eberline
	010019	31 ± 4	
222	010019	247 ± 6	Eberline
	010019	201 ± 12	
223	010019	64 ± 11	Eberline
	010019	362 ± 13	
224	010019	232 ± 4	Eberline
	010019	58.8 ± 6.6	
225	010019	188 ± 9	Eberline
	010019	362 ± 25	
226	010019	2.2 ± 0.4	Eberline
	010019	44 ± 16	
227	010019	51 ± 7	Eberline
	010019	198 ± 1.1	
228	010019	36 ± 5	Eberline
229	010019	386 ± 7	Eberline
	010019	51 ± 7	
230	010019	156 ± 6	Eberline
	010019	100 ± 10	
231	010019	1265 ± 15	Eberline
	010019	4 ± 2	
232	010019	2360 ± 90	Eberline

Film Collector Results, Roller Coaster, Double Tracks, May 25, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported By
233	010019 010019	38 ± 1 5 ± 2	Eberline
234	010019 010019	139 ± 2 140 ± 12	Eberline
235	010019 010019	23 ± 2 4 ± 2	Eberline
236	010019 010019	60 ± 2 16 ± 4	Eberline
237	010019 010019	127 ± 5 100 ± 10	Eberline
238	010019 010019	14.6 ± 1.3 179 ± 13	Eberline
239	010017 010017	116 ± 4 82 ± 9	Eberline
240	010017 010017	132 ± 3 129 ± 11	Eberline
241	010017 010017	366 ± 9 455 ± 21	Eberline
242	010017	Lost in Process	Eberline
243	010017 010017	108 ± 3 110 ± 9	Eberline
244	010017 010017	61 ± 2 91 ± 9	Eberline
245	010017 010017	64 ± 8 170 ± 4	Eberline
246	010017 010017	326 ± 6 158 ± 12	Eberline
247	010017 010017	2730 ± 80 2640 ± 130	Eberline
248	010017 010017	2700 ± 70 2800 ± 100	Eberline

Film Collector Results, Roller Coaster, Double Tracks, May 25, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported By
249	010017 010017	2730 ± 90 2670 ± 210	Eberline
250	010009	10300 ± 300	Tracerlab
251	010009	5410 ± 160	Tracerlab
252	010009	6200 ± 160	Tracerlab
253	10009	3310 ± 40	Isotopes, Inc.
254	10009	10500 ± 300	Isotopes, Inc.
255	10009	4300 ± 50	Isotopes, Inc.
256	10009	8980 ± 100	Isotopes, Inc.
257	10009	7030 ± 80	Isotopes, Inc.
258	10009	13900 ± 200	Isotopes, Inc.
259	10009	56100 ± 500	Isotopes, Inc.
260	10009	43100 ± 400	Isotopes, Inc.
261	10009	51100 ± 500	Isotopes, Inc.
262	10009	37700 ± 300	Isotopes, Inc.
301	10003	447 ± 6	Isotopes, Inc.
302	10003	668 ± 7	Isotopes, Inc.
303	10003	766 ± 8	Isotopes, Inc.
304	10003	980 ± 9	Isotopes, Inc.
305	10003.305	145.9 ± 2.9	Hazelton
306	10003	1.39 ± 0.12	Hazelton
307	10003	0.587 ± 0.102	Hazelton
308	100003	40.93 ± 2.66	Hazelton
309	100003	47.28 ± 3.22	Hazelton
310	10003	27.59 ± 2.54	Hazelton
601	10006	125.6 ± 2.76	Hazelton
602	10006	447.3 ± 13.9	Hazelton
603	10006	258.9 ± 3.4	Hazelton
604	10006	203 ± 4.7	Hazelton
605	10006	148.3 ± 1.92	Hazelton
606	10006.606	41.8 ± 0.5	Hazelton
607	10006.607	122.5 ± 2.7	Hazelton

FILM COLLECTOR RESULTS
ROLLER COASTER
Clean Slate I
May 25, 1963

Stake No.	Tracerlab Sample No.	dpm $^{239,240}Pu$	Data Reported By
801	9924	63.87 ± 2.49	Hazelton
802	9924	39.41 ± 3.94	Hazelton
803	9924	164.7 ± 5.3	Hazelton
804	9924	368 ± 16	Hazelton
805	9924	505 ± 12	Hazelton
806	9924	331 ± 13	Hazelton
807	9924	692 ± 15	Isotopes, Inc.
808	9924	714 ± 17	Isotopes, Inc.
809	9924	932 ± 20	Isotopes, Inc.
810	9924	485 ± 12	Isotopes, Inc.
811	9924	295 ± 6	Isotopes, Inc.
812	9924	984 ± 21	Isotopes, Inc.
813	9924	3080 ± 70	Tracerlab
814	9924	5200 ± 190	Tracerlab
815	9924	4840 ± 370	Tracerlab
816	9924	17700 ± 400	Tracerlab
817	9924	10500 ± 800	Tracerlab
818	9924	31200 ± 800	Tracerlab
819	9924	37700 ± 900	Tracerlab
820	9924	48000 ± 1100	Tracerlab
821	9923	15500 ± 300	Eberline
822		1260	
823	9923	11000 ± 300	Eberline
824	9923	3700 ± 100	Eberline
825	9923	2950 ± 40	Eberline
826	9923	3500 ± 40	Eberline
827	9923	24200 ± 100	Eberline
828	9923	950 ± 35	Eberline
829	9923	550 ± 18	Eberline
830	9923	2050 ± 50	Eberline

FILM COLLECTOR RESULTS
ROLLER COASTER
Clean Slate II
May 31, 1963

Stake No.	Tracerlab Sample No.	dpm ^{241}Am	dpm $^{239,240}Pu$	Data Reported By
829	10059		74.8 $\pm$ 2.8	Isotopes, Inc.
832	10058		18.9 $\pm$ 0.6	Isotopes, Inc.
840	10058	162 $\pm$ 7	8520 $\pm$ 190	Isotopes, Inc.
845	10059		209 $\pm$ 5	Isotopes, Inc.
847	10059		316 $\pm$ 5	Isotopes, Inc.
906	10032		5.43 $\pm$ 0.33	Isotopes, Inc.
907	10032		50.8 $\pm$ 1.8	Isotopes, Inc.
915	10032		23.0 $\pm$ 0.7	Isotopes, Inc.
919	10032		23.3 $\pm$ 0.8	Isotopes, Inc.

FILM COLLECTOR RESULTS
ROLLER COASTER
Clean Slate III
June 9, 1963

Stake No.	Tracerlab Sample No.	dpm	Data Reported By
100	10075	47.8 $\pm$ 1.5	Isotopes, Inc.
120	10076	33.3 $\pm$ 1.4	Isotopes, Inc.
801	10068	393 $\pm$ 9	Isotopes, Inc.
848	10069	380 $\pm$ 9	Isotopes, Inc.
901	10064	201 $\pm$ 5	Isotopes, Inc.

APPENDIX C

SUMMARY OF GLASS DEPOSITION SLIDES*

Particle size and character determinations by Isotopes, Inc.

* Operation Roller Coaster, Program 2 and 5 Activities, Samples Selected for Laboratory Analysis, by Meyers (3) reports a glass deposition slide from Clean Slate III and that nine, rather than seven, film collectors from Clean Slate II were selected for analysis. A check with the final computer run could yield no evidence of the missing data. The samples were either lost in process or erroneously reported as being selected for analyses.

LEGEND FOR APPENDIX C

Particle Size: The diameter of a circle of projected area equal to the projected area of the particle is listed at the head of each data column. The mean values of class intervals vary by the $\sqrt{2}$. Four columns under each size class represent respectively, from left to right particle shape, color, surface smoothness and activity. The symbols employed are:

(a) Shape:

S = spherical	? = unresolved optically
O = ovoid	A_i = agglomerate of i particles
I = irregular	

(b) Color: The upper entry is as observed by transmitted light. The entry below the slash is as by reflected light under crossed polarizers.

O = opaque	BR = brown
CL = clear	Y = yellow
W = white	A = amber
M = multi	

(c) Surface: S = smooth W = wrinkled I = irregular

(d) Activity: The number of alpha tracks per particle is listed or, where necessary, classified according to S, $\frac{S}{2}$ or $\frac{S}{4}$ where:

S corresponds to the case where the activity is so large that the tracks form a solid spot virtually to the edge of the circle defined by the length of an alpha track in the emulsion.

$\frac{S}{2}$ corresponds to the case of a solid spot of approximately half the radius of an S case.

$\frac{S}{4}$ corresponds to the case where the solid portion is about one quarter the radius of an S case.

Note that the number of tracks is dependent upon the autoradiographic exposure time.

The following samples are from 50 x 75 mm slides.

TABLE C.1 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON

Sample description: Event: Double Tracks Tracerlab No.: 10027 Type: Off-Site deposition slide Location: Stake 261
Percent sample area measured--28
Comments: Approximately 12 miles downwind, near most active air filter.

	0.85μ	1.1μ	1.6μ	2.2μ	3.1μ	4.5μ	6.4μ	9.0μ	12.7μ	18μ	25μ	36μ
Preparation a.				$S\frac{O}{BR}W\frac{S}{4}$					$S\frac{O}{BR}IS$			
1440 min.				$O\frac{O}{BR}W\frac{S}{8}$								
130 mm^2												
Preparation b.		$O\frac{Y}{BR}W\ 8$	$S\frac{CL}{--}W\ 40$	$S\frac{O}{BR}W\frac{S}{4}$						$I\frac{O}{BR}WS$	$I\frac{O}{BR}WS$	
1440 min.		$I\frac{Y}{?}W\ 6$	$I\frac{Y}{BR}W\ 4$									
125 mm^2			$S\frac{BR}{BR}W\ 100$									
Preparation c.						$S\frac{O}{BR}W\frac{S}{2}$						
1440 min.												
130 mm^2												
Preparation d.	$S\frac{2}{A}W\ 200$	A---160	$S\frac{?}{BR}W\frac{S}{4}$	$O\frac{?}{A}I\frac{S}{4}$		$A\frac{2}{BR}W\ 50$		$A\frac{?}{W}W\ 200$	$I\frac{O}{M}IS$			
1600 min.	------4	$S\frac{2}{BR}W\ 50$	$S\frac{?}{BR}W\frac{S}{4}$	$I\frac{2}{BR}W\ 120$		A CL ? 50			$A\frac{O}{M}IS$			
144 mm^2	------8	$O\frac{2}{A}\ ?\ 50$	$A\frac{?}{BR}W\frac{S}{4}$									
			$O\frac{?}{BR}W\frac{S}{8}$									
			$A\frac{2}{BR}W\ 80$									

TABLE C.1 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON
(Continued)

	0.85μ	1.1μ	1.6μ	2.2μ	3.1μ	4.5μ	6.4μ	9.0μ	12.7μ	18μ	25μ	36μ
Preparation e.	O $\frac{CL}{---}$? 8	O $\frac{CL}{---}$ S 14	S $\frac{?}{BR}$ W $\frac{S}{4}$	S $\frac{?}{BR}$ W $\frac{S}{4}$	I $\frac{?}{BR}$ W S							
1600 min.		-------$\frac{S}{8}$	A_3 $\frac{?}{BR}$ W 250	S $\frac{?}{BR}$ W $\frac{S}{2}$	S $\frac{O}{BR}$ W $\frac{S}{2}$							
144 mm²		$A_3 \frac{A}{?}$? 56										

Total 673 mm²

TABLE C.2 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON

Sample description: Event: Double Tracks Tracerlab No.: 10027 Type: Off-Site deposition slide Location: Stake 261
Percent sample area measured: 28

PHOSPHOR AUTORADIOGRAPHY DATA:

Zenith Plate, 1000 min.

Reticle value	3	4	5	6	7	8	9	10	11	12	13	
**Particle size, PuO_2	0.4μ	0.5μ	0.8μ	1.0μ	1.4μ	2.1μ	3.0μ	4.6μ	7.3μ	14.0μ	32.0μ	
**Particle size, R.C.C.	1.2μ	1.5μ	2.2μ	2.9μ	4.0μ	5.8μ	8.7μ	14.0μ	25.0μ	50.0μ	115.0μ	
Frequency of spot occurrence	1	2	3	3	4	3	4	4	4	4	1	33 Images 24 cm²

NUCLEAR TRACK AUTORADIOGRAPHY DATA (Preparations same as Table 1).

	3	4	5	6	7	8	9	10	11	12	13
Preparation a.								2.2μ	12.7μ 2.2μ		
Preparation b.										18.0μ 2.2μ 1.6μ	25.0μ 1.6μ 1.6μ 1.1μ
Preparation c.		can not correlate									
Preparation d.					1.6μ/$\frac{S}{4}$ 9.0μ /200				12.7μ/S 2.2μ/$\frac{S}{4}$ 12.7μ/S 1.6μ/$\frac{S}{4}$		

**Calibration by R. Carter, UK, AEA

TABLE C.2 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON (Continued)

	3	4	5	6	7	8	9	10	11	12	13
Preparation d. (cont')									$1.6\mu/\frac{S}{9}$		
									$1.6\mu/\frac{S}{8}$		
									$1.1\mu/160$		
									$2.2\mu/120$		
									$4.5\mu/50$		
									$1.1\mu/50$		
									$1.1\mu/50$		
									$4.5\mu/50$		
									$1.6\mu/80$		
									$0.85\mu/200$		
									$0.85\mu/4$		
									? /8		
Preparation e.			$1.6\mu/250$	$1.1\mu/\frac{S}{8}$		$2.2\mu/\frac{S}{2}$	$3.1\mu/S$			$28\mu/S$	
			$1.1\mu/56$	$1.6\mu/\frac{S}{4}$		$3.1\mu/\frac{S}{2}$	$2.2\mu/\frac{S}{4}$			$1.1\mu/14$	
							$0.8\mu/8$				

TABLE C.3 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON

Sample description: Event: Clean Slate I Tracerlab No.: 9911 Type: Deposition Slide Location: Stake 822

	0.85μ	1.1μ	1.6μ	2.2μ	3.1μ	4.5μ	6.4μ	9.0μ	12.7μ	18μ	25μ	36μ
Preparation a.				$S\frac{CL}{--}S$ 27			$O\frac{O}{--}$? 2	$S\frac{O}{BR}$ W 8	A_{10} ? ? 70	$S\frac{O}{BR}$ W 100		
132 mm^2				$O\frac{CL}{--}S$ 5			A ? ? 9			$S\frac{O}{M}$W S		
360 min.				$S\frac{CL}{--}S$ 6								
Preparation b.							$S\frac{O}{M}W\frac{S}{8}$	A_4 ? ? $\frac{S}{8}$	I $\frac{O}{M}$ W $\frac{S}{4}$	A_3 ? ? 200		
78 mm^2												
1440 min.												
Preparation c.				$S\frac{BR}{BR}$ W 30				$O\frac{O}{M}W\frac{S}{2}$				$S\frac{O}{BR}$? 250
96 mm^2												$S\frac{O}{--}I\frac{S}{8}$

TABLE C.4 CLASSIFICATION OF PARTICLES WITH PROJECTED AREA EQUIVALENT DIAMETER > 0.5 MICRON

Sample description: Event: Clean Slate I   Tracerlab No.: 9911   Type: Deposition Slide   Location: Stake 822

PHOSPHOR AUTORADIOGRAPHY DATA:											
Zenith Plate, 1000 min.											
Reticle value	3	4	5	6	7	8	9	10	11	12	13
**Particle size, PuO_2											
**Particle size, R.C.C.											
Frequency of occurrence	3	3	5	4	7	4	8	8	1		
NUCLEAR TRACK AUTORADIOGRAPHY DATA (same preparations as Table 3):											
Preparation a.							18μ/114		25μ/S		
Preparation b.			9μ/$\frac{S}{8}$		12.7μ/$\frac{S}{8}$	18μ/$\frac{S}{4}$					
					18μ/200 14μ/200 10μ/200						
Preparation c.						40μ/$\frac{S}{8}$	35μ/250	12.7μ/$\frac{S}{2}$			
						2.2μ/30					

**Calibration by R. Carter, UK, AEA

APPENDIX D SUMMARY OF AIR SAMPLES

AIR FILTER RESULTS AT POPULATED LOCATIONS
ROLLER COASTER
Double Tracks
May 15, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Beatty	1245-5/14 1300-5/15	2989	6377	11.25
	1300-5/15 1320-5/16	3102	146	.25
Death Valley Junction	1630-5/14 1630-5/15	2570	1085	2.23
	1630-5/15 1630-5/16	2570	215	.44
Furnace Creek	1300-5/14 1230-5/15	1896	182	.57
Goldfield	0900-5/14 0900-5/15	2285	9	.02
	0930-5/16 0930-5/17	2326	13	.03
Goldpoint	1912-5/14 1102-5/15	1428	29	.11
	1111-5/15 0923-5/16	1740	165	.51
Lathrop Wells	0630-5/14 0630-5/15	1346	4	.01
	0635-5/15 0640-5/16	1368	300	1.16
Lida	1630-5/14 0800-5/15	1291	22	.09
Lida Junction	1400-5/14 1915-5/14	624	5	.04
	1920-5/14 0718-5/15	1428	1752	6.5

Air Filter Results at Populated Locations, Roller Coaster, Double Tracks, May 15, 1963 (Continued)

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Lida Junction	0722-5/15 1400-5/15	789	66	.44
Scotty's Junction	0830-5/14 Motor out-5/15	2230	5114	12.09*
	0830-5/15 0830-5/16	2630	335	.67
Stake 76 (Asphalt Batch Plant)	2100-5/14 1157-5/15	1280	7045	29.03
	1112-5/15 0254-5/16	1470	140	.50
Stake 435 (Clark Station)	1853-5/14 1453-5/15	1853	10	.03
	1530-5/15 1330-5/16	1945	11	.03
Tonopah	1700-5/14 1700-5/15	2534	15	.03
	1700-5/15 1800-5/16	2528	30	.06
Tonopah Airport	1037-5/14 1100-5/15	2632	20	.04
	1100-5/15 1035-5/16	2508	25	.05
Tonopah Test Range	1130-5/14 1130-5/15	2652	18	.04
	1130-5/15 1130-5/16	2652	36	.07
Warm Springs	0600-5/14 0600-5/15	2244	18	.04
	0600-5/15 0600-5/16	2346	40	.09

*Air flow at this station was estimated due to a burned out motor.

Backgrounds of .02 - .04 dpm/M^3 are common in this area.

AIR FILTER RESULTS AT UNPOPULATED LOCATIONS
ROLLER COASTER
Double Tracks
May 15, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Stake 262	1905-5/14 1247-5/15	1803	66,204	193.69
	1310-5/15 0634-5/16	1530	165	.57
Stake 14	0650-5/15 0050-5/16	1650	18	.06
Stake 36	1840-5/14 2304-5/15	2560	1354	2.85
Stake 28	1900-5/14 0454-5/16	3000	3765	6.62
Stake 208	2036-5/14 0348-5/15	780	6	.04
	0910-5/15 2240-5/15	1400	52	.20
Stake 222	2010-5/14 0958-5/15	1175	190	.85
	0958-5/15 1650-5/16	1250	24	.10
Stake 240	1942-5/14 1118-5/15	1484	71	.25
	1058-5/15 0316-5/16	1520	55	.19
Stake 305	1819-5/14 0741-5/15	1430	1011	3.73
	0753-5/15 0241-5/16	1770	32	.10
Stake 606	1753-5/14 0615-5/15	1180	673	3.01
	0630-5/15 2345-5/15	1820	301	.87

AIR FILTER RESULTS
ROLLER COASTER
Clean Slate I
May 25, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Alamo	0630-5/24 0630-5/25	2346	BKG	BKG
	0630-5/25 0600-5/26	2305	33.5	.08
	0600-5/26 0600-5/27	2326	12	.03
Beatty	1300-5/24 1210-5/25	2932	BKG	BKG
	1210-5/25 1200-5/26	3060	BKG	BKG
	1200-5/26 1400-5/27	3187	BKG	BKG
Caliente	0755-5/24 0645-5/25	2542	BKG	BKG
	0650-5/25 0845-5/26	2614	BKG	BKG
	0850-5/26 0730-5/27	2265	BKG	BKG
Currant	0700-5/24 0700-5/25	1061	BKG	BKG
	0700-5/25 0700-5/26	919	BKG	BKG
	0700-5/26 0700-5/27	989	BKG	BKG
Death Valley Junction	1630-5/24 1630-5/25	2611	BKG	BKG
	1630-5/25 1630-5/26	2632	BKG	BKG

Air Filter Results, Roller Coaster, Clean Slate I, May 25, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Death Valley Junction	1630-5/26 1630-5/27	2693	BKG	BKG
Diablo	0700-5/24 Motor out	----	----	----
	0715-5/25 0935-5/26	1202	BKG	BKG
	0930-5/26 0635-5/27	982	BKG	BKG
Ely	Sample data not available	----	BKG	BKG
Twin Springs	0700-5/24 0700-5/25	1042	BKG	BKG
	0700-5/25 0700-5/26	919	BKG	BKG
	0700-5/26 0700-5/27	1020	BKG	BKG
Furnace Creek	1300-5/24 1400-5/25	2550	12	.02
	1400-5/25 1300-5/26	2444	BKG	BKG
	1300-5/26 1335-5/27	2654	BKG	BKG
Goldfield	0900-5/24 0900-5/25	2346	BKG	BKG
	0900-5/25 0900-5/26	2366	BKG	BKG
	0900-5/26 0900-5/27	2285	BKG	BKG
Hiko	0900-5/24 0900-5/25	2632	BKG	BKG
	0900-5/25 0900-5/26	2632	12	.02
	0900-5/26 0900-5/27	2632	BKG	BKG

Air Filter Results, Roller Coaster, Clean Slate I, May 25, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Indian Springs	0800-5/24 0800-5/25	612	BKG	BKG
	0800-5/25 0800-5/26	612	BKG	BKG
	0800-5/26 0800-5/27	590	BKG	BKG
Las Vegas	0945-5/24 1610-5/27	4013	10	.01
Lathrop Wells	0625-5/26 0630-5/27	2387	145	.32
	0635-5/27 0615-5/28	2422	21	.05
Lund	0700-5/24 0815-5/25	2661	10	.02
	0815-5/25 -----5/26	Not able to compute air volume	BKG	BKG
	0640-5/26 0800-5/27	2799	24.5	.05
Mesquite	0730-5/24 0730-5/25	2774	13	.02
	0730-5/25 0730-5/26	2917	13	.02
	0730-5/26 0730-5/27	2774	15.5	.03
Pahrump	1600-5/23 1600-5/25	2182	BKG	BKG
	1600-5/25 1600-5/26	2301	BKG	BKG
Pioche	0800-5/24 0800-5/25	2570	12.5	.03
	0800-5/25 0800-5/26	2550	11.5	.02

Air Filter Results, Roller Coaster, Clean Slate I, May 25, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Pioche	0800-5/26 0800-5/27	2428	15.5	.03
Scotty's Junction	0700-5/24 0830-5/25	2185	BKG	BKG
	0930-5/25 0930-5/26	1979	BKG	BKG
	0930-5/26 1130-5/27	2122	BKG	BKG
Tonopah	1800-5/24 1805-5/25	2428	BKG	BKG
	1805-5/25 1800-5/26	2488	BKG	BKG
	1800-5/26 1900-5/27	2380	11	.02
Tonopah Test Range	1130-5/24 1100-5/27	7900	BKG	BKG
Warm Springs	0600-5/24 0630-5/25	2707	BKG	BKG
	0630-5/25 1645-5/25	625	BKG	BKG
	1645-5/25 1600-5/26	2569	11	.02
	0600-5/26 0600-5/27	2550	BKG	BKG

AIR FILTER RESULTS
ROLLER COASTER
Clean Slate II
May 31, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Tonopah Test Range	1130-5/31 1110-6/01	2591	13	.03
Warm Springs	0600-5/31 0600-6/01	2346	10	.02
	0600-6/01 0600-6/02	2346	10	.02
Stake 240	1620-5/30 1125-5/31	1372	BKG	BKG
	1157-5/31 1205-6/01	1754	BKG	BKG
Stake 435	1525-5/30 1050-5/31	1466	BKG	BKG
	1105-5/31 1205-6/01	1466	BKG	BKG
Stake 808	1800-5/30 1010-5/31	1332	BKG	BKG
	1320-5/31 0532-6/01	1377	BKG	BKG
Stake 816	1745-5/30 1245-5/31	1938	BKG	BKG
	1313-5/31 0453-6/01	1597	BKG	BKG
Stake 824	1720-5/30 1330-5/31	1735	29	.08
	1335-5/31 1445-6/01	2389	BKG	BKG
Stake 832	1655-5/30 0943-5/31	1599	59	.19

Air Filter Results, Roller Coaster, Clean Slate II, May 31, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Stake 832	1405-5/31 0629-6/01	1505	BKG	BKG
Stake 838	1630-5/30 1000-5/31	1904	49	.14
Stake 843	1620-5/30 0825-5/31	1738	11	.03
	1455-5/30 0625-5/31	1581	BKG	BKG
Stake 848	1600-5/30 0954-5/31	1582	399	1.33
	1510-5/31 0946-6/01	1591	BKG	BKG
Stake 913	1535-5/30 1230-5/31	1848	BKG	BKG
Stake 915	1540-5/31 1434-6/01	2199	BKG	BKG
Stake 921	1510-5/30 1100-5/31	1020	BKG	BKG

NOTE: Readings below .02 DPM/M^3 are background.

Locations of Air Filters Collected May 30, June 1, 1963 and Processed with No Results Above Background Clean Slate II

Alamo	Mesquite
Beatty	Pahrump***
Caliente*	Pioche
Currant	Scotty's Junction
Death Valley Junction, Calif.	St. George, Utah
Diablo	Tonopah
Ely	Warm Springs
Enterprise	Warm Springs Ranch
Twin Springs	Eureka
Furnace Creek, California**	Blue Jay
Goldfield	Garrison
Hiko	Groom Lake
Indian Springs	Lida
Las Vegas***	Lida Junction
Lathrop Wells	Tonopah Airport
Lund	

* No filter for June 1
** No filter for May 30 and June 1
*** Continuous Sample

AIR FILTER RESULTS
ROLLER COASTER
Clean Slate III
June 9, 1963

Location	Time-Date Collection	Air Volume M^3	Counts per Minute	Disintegrations per Minute/M^3
Stake 848	1400-6/08 0900-6/09	2002	787	2.07
Stake 838	1435-6/08 1053-6/09	2408	69	0.18

Locations of Air Filters Collected June 8 - June 10, 1963,
and Processed with No Results Above Background
Clean Slate III

Stake 240*
Stake 435*
Stake 808*
Stake 816*
Stake 824*
Stake 832*
Stake 838*
Stake 843*
Stake 848*
Stake 915*
Stake 921*
Alamo
Beatty
Blue Jay
Caliente
Cedar Pass
Currant
Death Valley Junction, Calif.
Diablo
Ely
Enterprise
Eureka
Furnace Creek, California
Goldfield
Groom Lake
Hiko
Indian Springs
Lathrop Wells
Lida Junction
Lund
Mesquite
Pahrump
Pioche
Scotty's Junction
Springdale
St. George, Utah
Tonopah
Tonopah Airport
Twin Springs
Warm Springs
Warm Springs Ranch

*No filter June 10

Radiochemical Analysis of Roller Coaster Air Filter Samples Collected by the U.S. Public Health Service

Sample No.	Location	Event	TLW Analysis No.	$^{239,240}Pu$ Activity (dpm)	U_3O_8** (Micro-grams)	Yield* Percent	Pu Count Time Min.	Anal/Mon***
04	Alamo	Clean Slate I	CPA-2503	$2.02 \pm 0.06E\ 02$	14.3	19.6R	810	5.9E 00****
05	Beatty	Double Tracks	2504	$3.46 \pm 0.07E\ 04$	0.516	58.0	45	5.4E 00
06	Beatty	Double Tracks	2505	$9.50 \pm 0.28E\ 02$	14.3	15.3R	400	6.5E 00
07	Death Valley Junction	Double Tracks	2506	$6.56 \pm 0.17E\ 03$	0.718	45.3	44	6.1E 00
08	Death Valley Junction	Double Tracks	2507	$1.33 \pm 0.04E\ 03$	BKG	13.1R	933	5.8E 00
12	Furnace Creek	Double Tracks	2508	$1.50 \pm 0.08E\ 03$	0.230	5.0R	933	7.5E 00
13	Goldpoint	Double Tracks	2509	$7.12 \pm 0.25E\ 01$	5.52	66.4	240	2.5E 00
14	Goldpoint	Double Tracks	2510	$3.35 \pm 0.13E\ 02$	BKG	14.8R	300	2.0E 00
18	Lathrop Wells	Double Tracks	2511	$1.55 \pm 0.04E\ 03$	0.068	48.1	44	5.2E 00
19	Lathrop Wells	Clean Slate I	2512	$7.46 \pm 0.31E\ 02$	BKG	11.1R	300	5.1E 00
20	Lathrop Wells	Clean Slate I	2513	$8.21 \pm 0.36E\ 01$	4.93	31.2	300	3.9E 00
22	Lida Junction	Double Tracks	2514	$8.98 \pm 0.26E\ 03$	4.35	26.3	45	5.1E 00
23	Lida Junction	Double Tracks	2515	$4.50 \pm 0.18E\ 01$	4.74	66.0	240	6.9E-01
24	Lund	Clean Slate I	2516	$1.31 \pm 0.08E\ 02$	0.921	12.9R	300	5.2E 00
25	Scotty's Junction	Double Tracks	2517	$2.59 \pm 0.08E\ 04$	2.74	28.6	40	5.1E 00
26	Scotty's Junction	Double Tracks	2518	$2.16 \pm 0.05E\ 03$	0.176	56.5R	856	6.6E 00
27	Tonopah	Double Tracks	2519	$2.81 \pm 0.15E\ 01$	4.65	43.1	300	1.9E 00
28	Tonopah	Double Tracks	2520	$4.84 \pm 0.19E\ 01$	BKG	49.1	300	1.6E 00
31	Tonopah Test Range	Double Tracks	2521	$3.30 \pm 0.16E\ 01$	1.10	20.3	600	1.8E 00
32	Tonopah Test Range	Double Tracks	2522	$6.47 \pm 0.28E\ 01$	0.226	33.6	300	1.8E 00
35	Warm Springs	Double Tracks	2523	$1.92 \pm 0.05E\ 02$	BKG	44.4	400	1.1E 01
36	Warm Springs	Double Tracks	2524	$3.25 \pm 0.12E\ 02$	1.22	29.3	300	8.1E 00
43	Stake 14	Double Tracks	2525	$5.30 \pm 0.22E\ 01$	BKG	22.6	600	2.9E 00
44	Stake 28	Double Tracks	2526	$2.23 \pm 0.05E\ 04$	5.02	38.5	45	5.9E 00
45	Stake 36	Double Tracks	2527	$7.34 \pm 0.15E\ 03$	2.23	64.8	45	5.4E 00

*R - Rework

** Determined by fluorometry

***Ratio dpm/cpm
See Section 2.4- Factor calculated to 5.2

****5.9E00 = $5.9 \times 10^{0} = 5.9$

Radiochemical Analysis of Roller Coaster Air Filter Samples Collected by the U.S. Public Health Service (Continued)

Sample No.	Location	Event	TLW Analysis No.	$^{239,240}Pu$ Activity (dpm)	U_3O_8 Micro-grams)	Yield* %	Pu Count Time Min.	Anal/Mon
46	Stake 76 (ABP)	Double Tracks	CPA-2528	3.67 ± 0.09E 04	2.19	40.0	45	5.2E 00
47	Stake 76	Double Tracks	2529	8.48 ± 0.36E 02	BKG	10.2R	300	6.1E 00
48	Stake 108	Clean Slate I	2530	1.49 ± 0.06E 02	0.693			1.5E 01
49	Stake 108	Clean Slate I	2531	6.17 ± 0.22E 01	0.576	40.6	400	2.1E 00
50	Stake 208	Double Tracks	2532	6.04 ± 0.17E 01	1.51	53.0	510	1.2E 00
51	Stake 222	Double Tracks	2533	9.43 ± 0.58E 02	2.63	8.4	300	9.4E 00
52	Stake 222	Double Tracks	2534	1.63 ± 0.08E 02	9.82	9.8	600	6.8E 00
53	Stake 240	Double Tracks	2535	3.44 ± 0.16E 02	0.201	13.7	400	4.8E 00
54	Stake 240	Double Tracks	2536	2.36 ± 0.15E 02	BKG	9.9	300	4.3E 00
55	Stake 262	Double Tracks	2537	3.65 ± 0.06E 05	9.78	74.6	45	5.5E 00
56	Stake 262	Double Tracks	2538	1.76 ± 0.02E 03	0.106	42.8	1000	1.0E 01
57	Stake 305	Double Tracks	2539	4.83 ± 0.17E 03	0.258	18.6	44	4.8E 00
58	Stake 305	Double Tracks	2540	1.03 ± 0.04E 02	0.886	12.4	810	3.2E 00
59	Stake 606	Double Tracks	2541	3.40 ± 0.11E 03	1.81	24.3	44	5.1E 00
60	Stake 606	Double Tracks	2542	1.83 ± 0.02E 03	1.23	26.1	400	6.1E 00
61	Stake 808	Clean Slate I	2543	6.75 ± 0.24E 03	4.68	25.9	40	6.1E 00
62	Stake 816	Clean Slate I	2544	7.51 ± 0.17E 04	25.8	59.2	45	7.5E 00
63	Stake 824	Clean Slate I	2545	8.81 ± 0.33E 04	6.68	18.5	40	8.8E 00
64	Stake 824	Clean Slate I	2546	2.63 ± 0.12E 02	2.21	37.9	240	8.8E 00
65	Stake 824	Clean Slate II	2547	2.75 ± 0.12E 02	BKG	43.1	240	9.1E 00
66	Stake 832	Clean Slate I	2548	8.16 ± 0.23E 02	5.17	22.5	300	4.9E 00
67	Stake 832	Clean Slate I	2549	8.94 ± 0.28E 01	BKG	44.0	400	4.1E 00
68	Stake 832	Clean Slate II	2550	4.29 ± 0.12E 02	BKG	38.1	400	7.3E 00
69	Stake 838	Clean Slate I	2551	1.30 ± 0.06E 02	BKG	24.9	300	7.2E 00
70	Stake 838	Clean Slate I	2552	1.09 ± 0.04E 02	0.912	28.1	510	5.4E 00

*R - Rework

Radiochemical Analysis of Roller Coaster Air Filter Samples Collected by the U.S. Public Health Service (Continued)

Sample No.	Location	Event	TLW Analysis No.	$^{239,240}Pu$ Activity (dpm)	U_3O_8 (Micro-grams)	Yield %	Pu Count Time Min.	Anal/Mon
71	Stake 838	Clean Slate II	CPA-2553	4.68 ± 0.28E 02	3.98	7.4	400	9.6E 00
72	Stake 838	Clean Slate III	2554	6.78 ± 0.35E 02	1.36	12.8	300	9.8E 00
73	Stake 848	Clean Slate I	2555	3.85 ± 0.16E 01	0.876	24.6	510	2.4E-01
74	Stake 848	Clean Slate II	2556	3.94 ± 0.14E 03	13.9	22.6	40	9.9E 00
75	Stake 848	Clean Slate III	2557	6.83 ± 0.21E 03	5.83	24.3	45	8.7E 00
76	Stake 913	Clean Slate I	2558	1.90 ± 0.06E 02	BKG	40.1	300	5.9E 00
77	Stake 921	Clean Slate I	2559	4.81 ± 0.20E 01	0.044	25.1	856	4.0E-02

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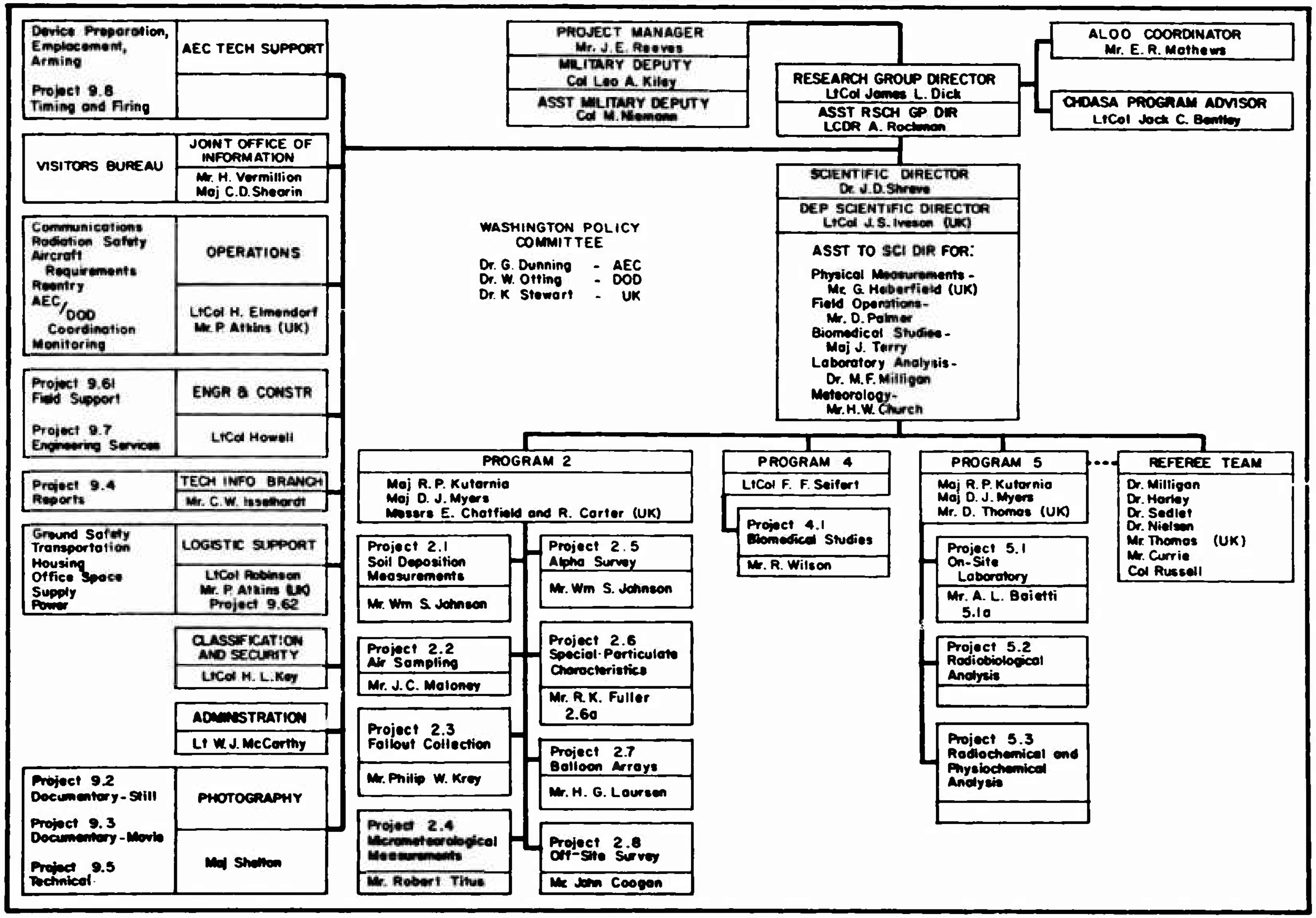
ROLLER COASTER ORGANIZATIONAL CHART



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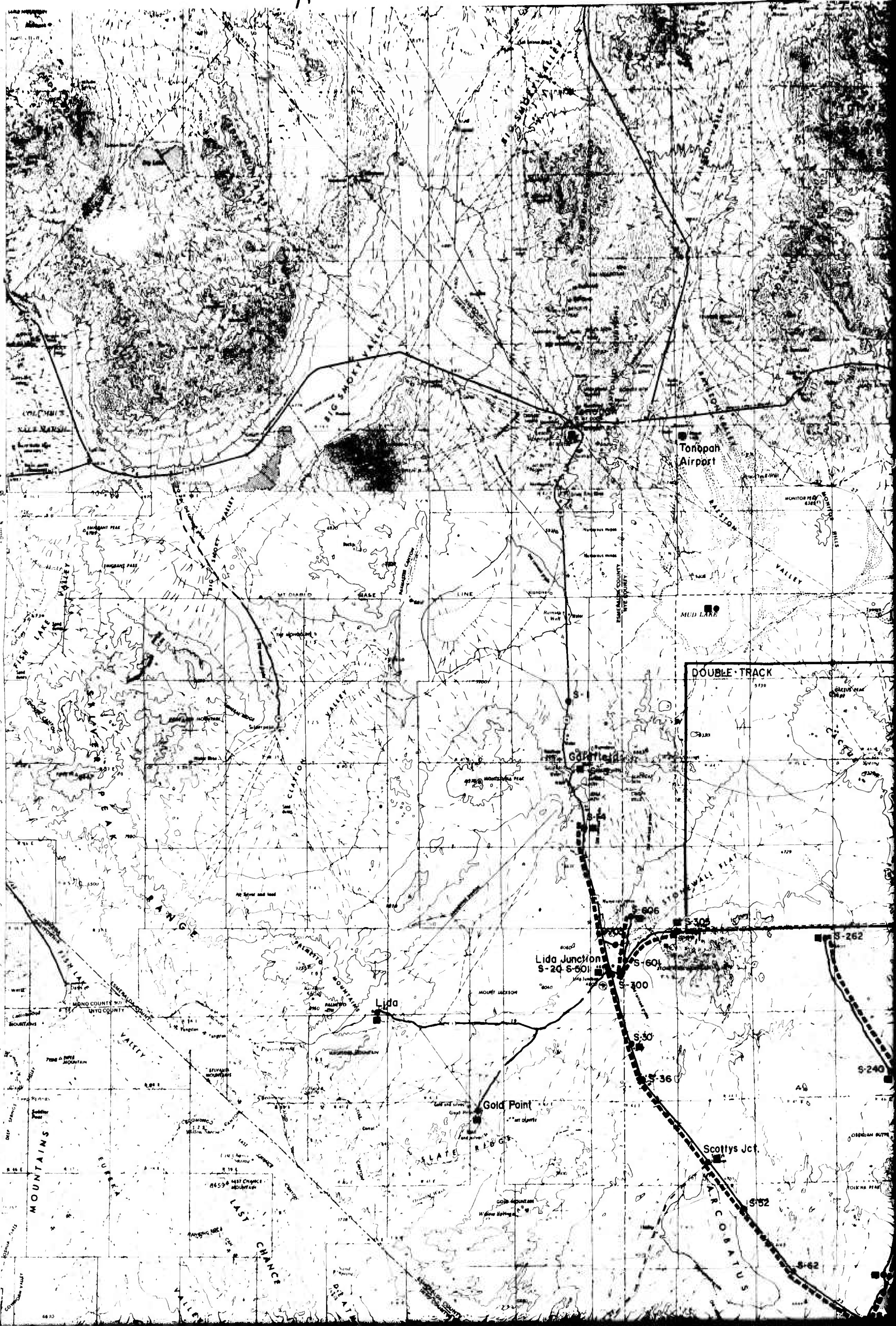
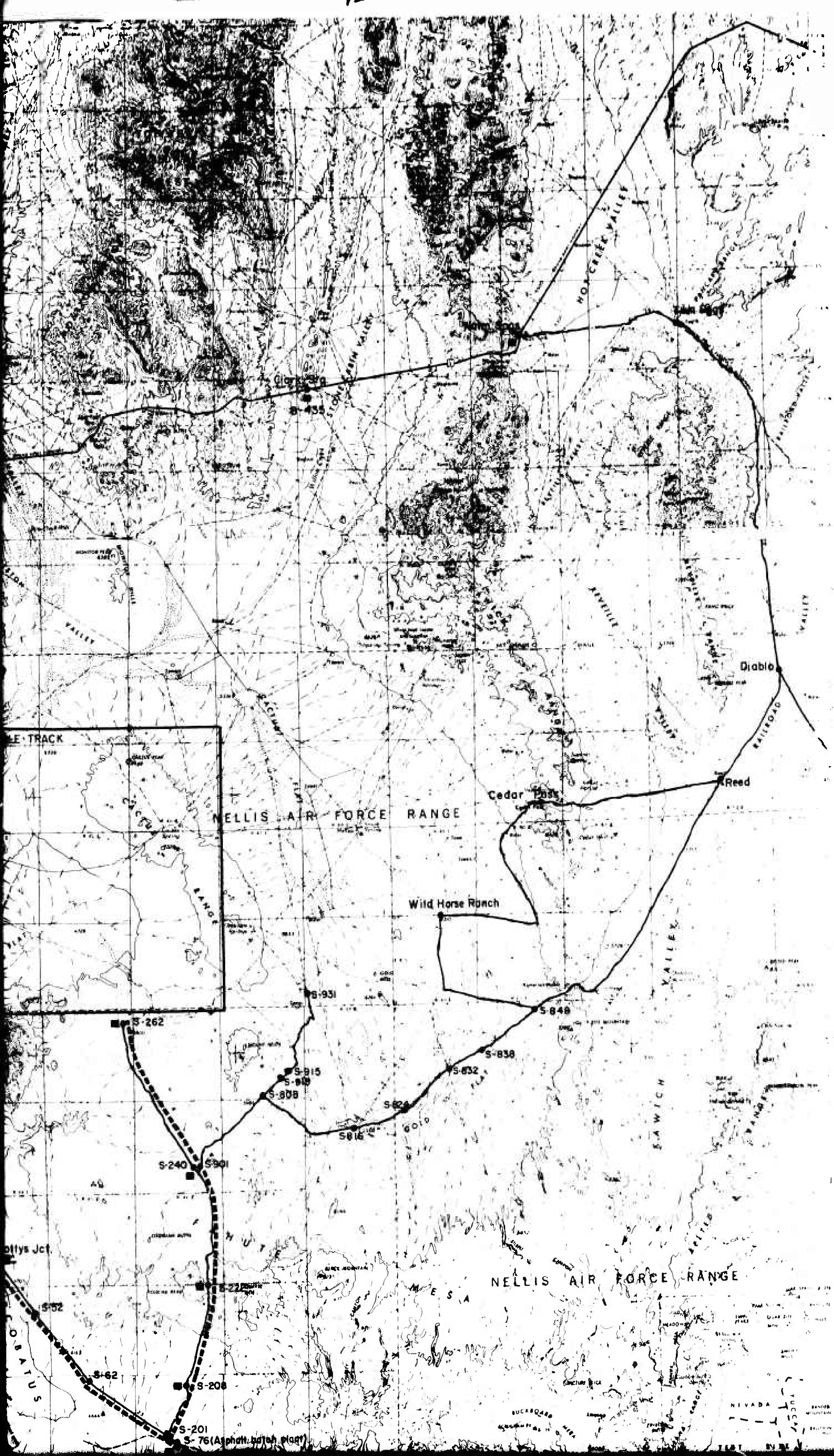
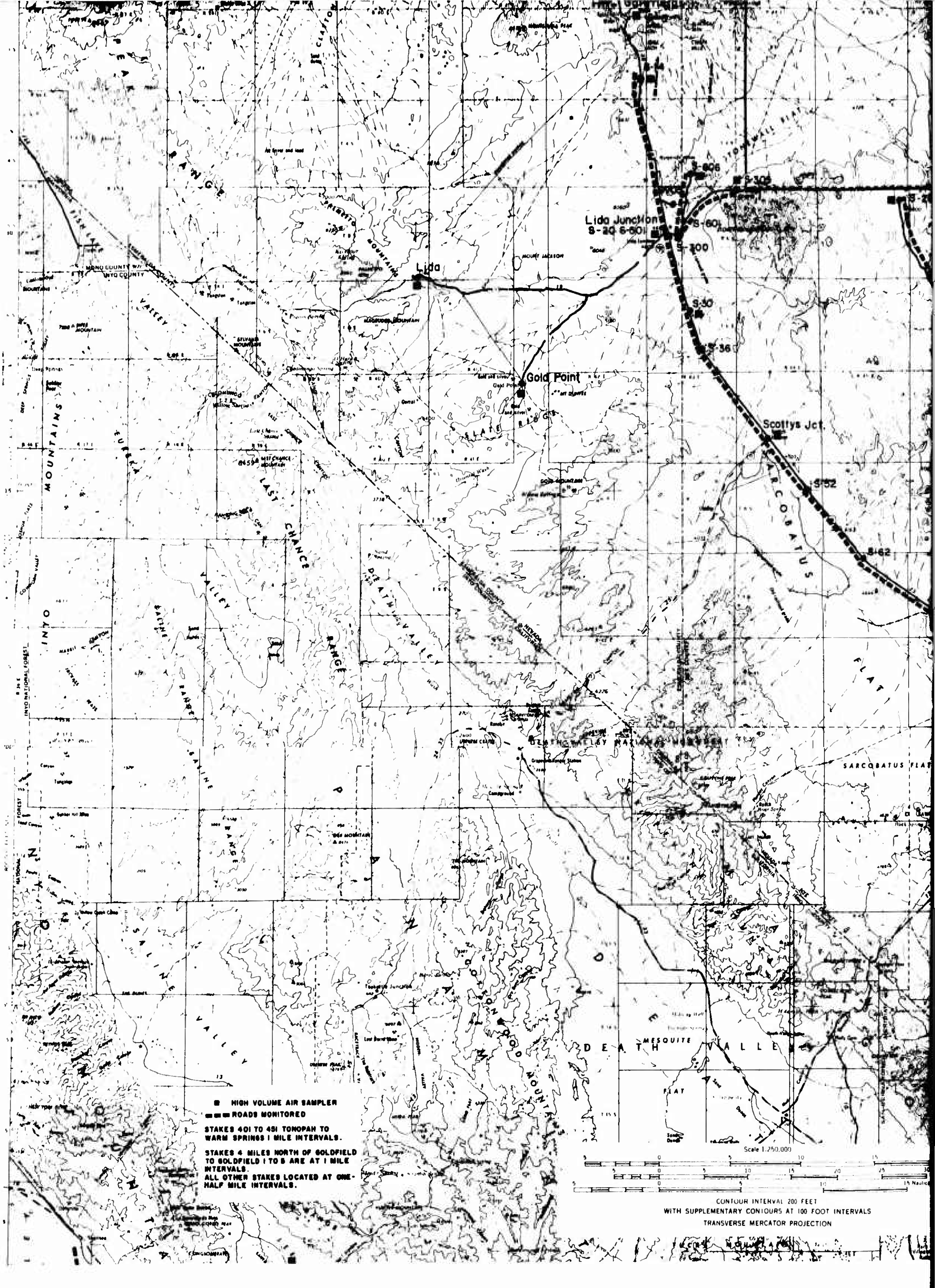


BIG SMOKY VALLEY
Tonopah Airport
RALSTON VALLEY
MUD LAKE
DOUBLE TRACK
S-1
STONEWALL FLAT
S-606
S-305
S-262
Lida Junction
S-20 S-601
S-601
S-300
Lida
PALMETTO MOUNTAINS
S-30
S-36
S-240
Gold Point
SLATE RIDGE
Scottys Jct.
S-52
S-62
LAST CHANCE
EUREKA
MOUNTAINS
FISH LAKE VALLEY
RANGE

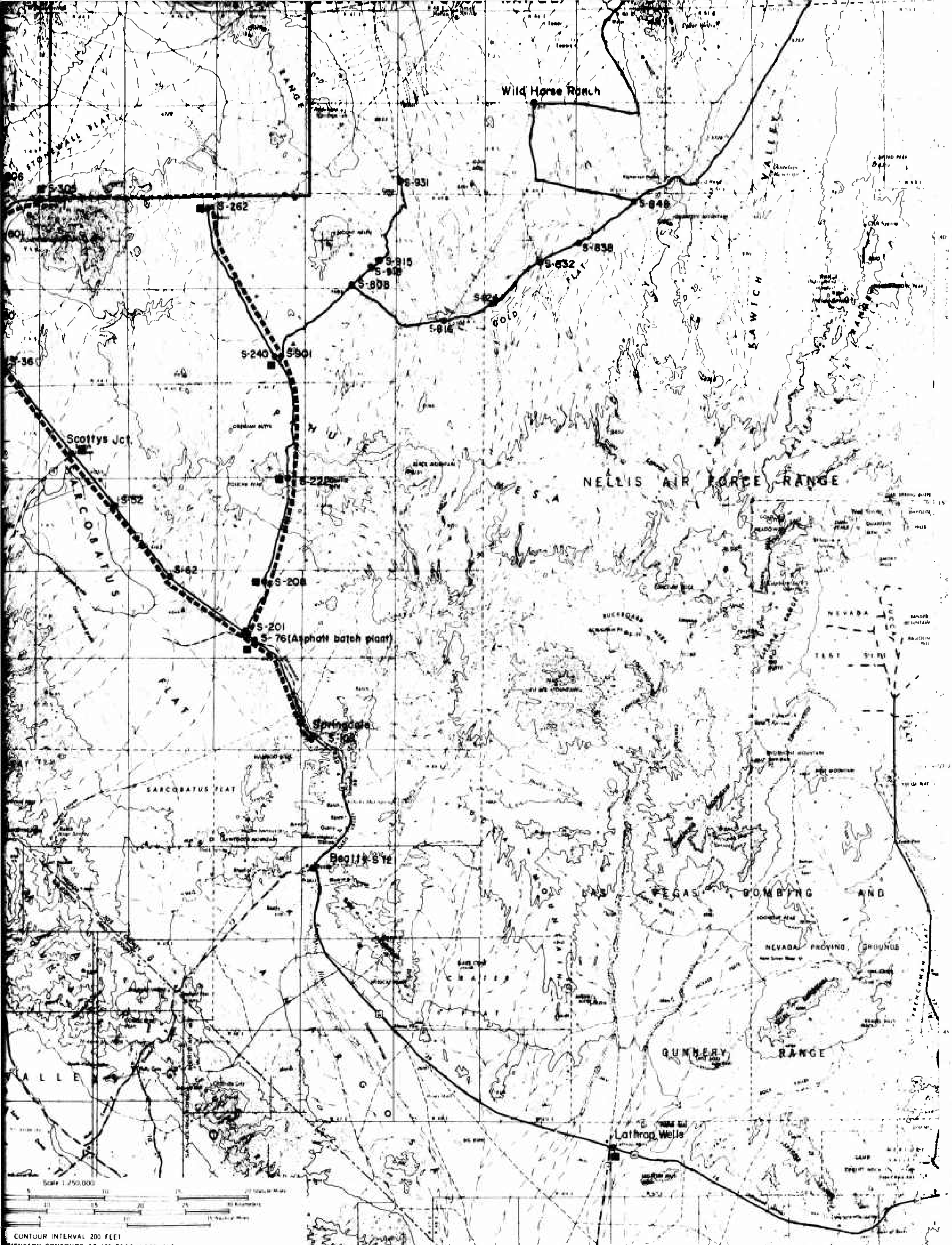


Warm Spg
S-435
STONE CABIN VALLEY
HOT CREEK VALLEY
Diablo
RAILROAD
VALLEY
Reed
Cedar Pass
NELLIS AIR FORCE RANGE
CACTUS
RANGE
LE TRACK
Wild Horse Ranch
S-931
S-848
S-838
S-832
S-824
S-816
S-915
S-808
S-262
S-240
S-901
GOLD
KAWICH
VALLEY
ottys Jct.
S-222
S-52
S-62
S-208
S-201
S-76 (Asphalt batch plant)
MESA
NELLIS AIR FORCE RANGE
NEVADA



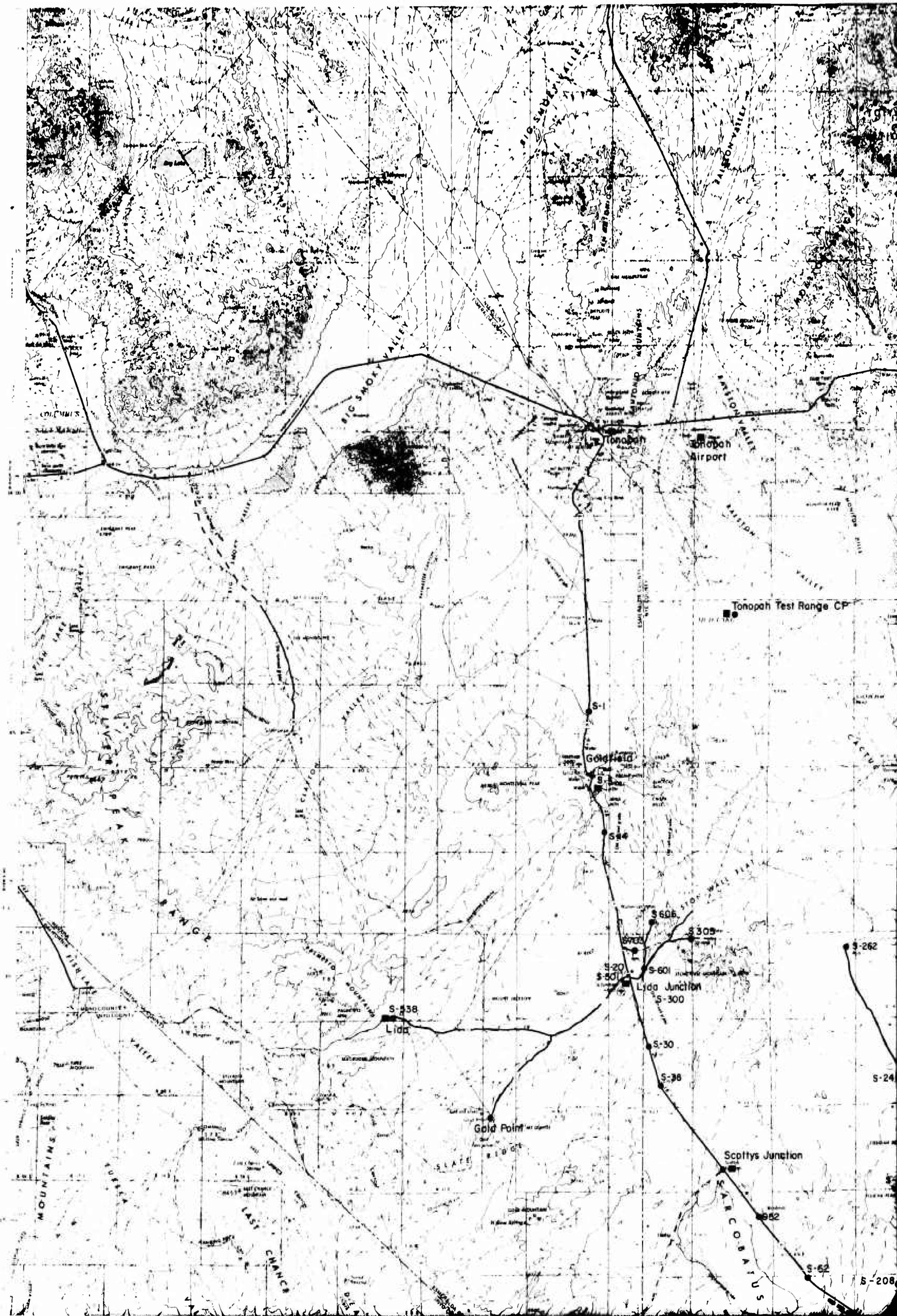
C

(FIG 2.1.) MARKING STAKE NUMBERING SYSTEM,



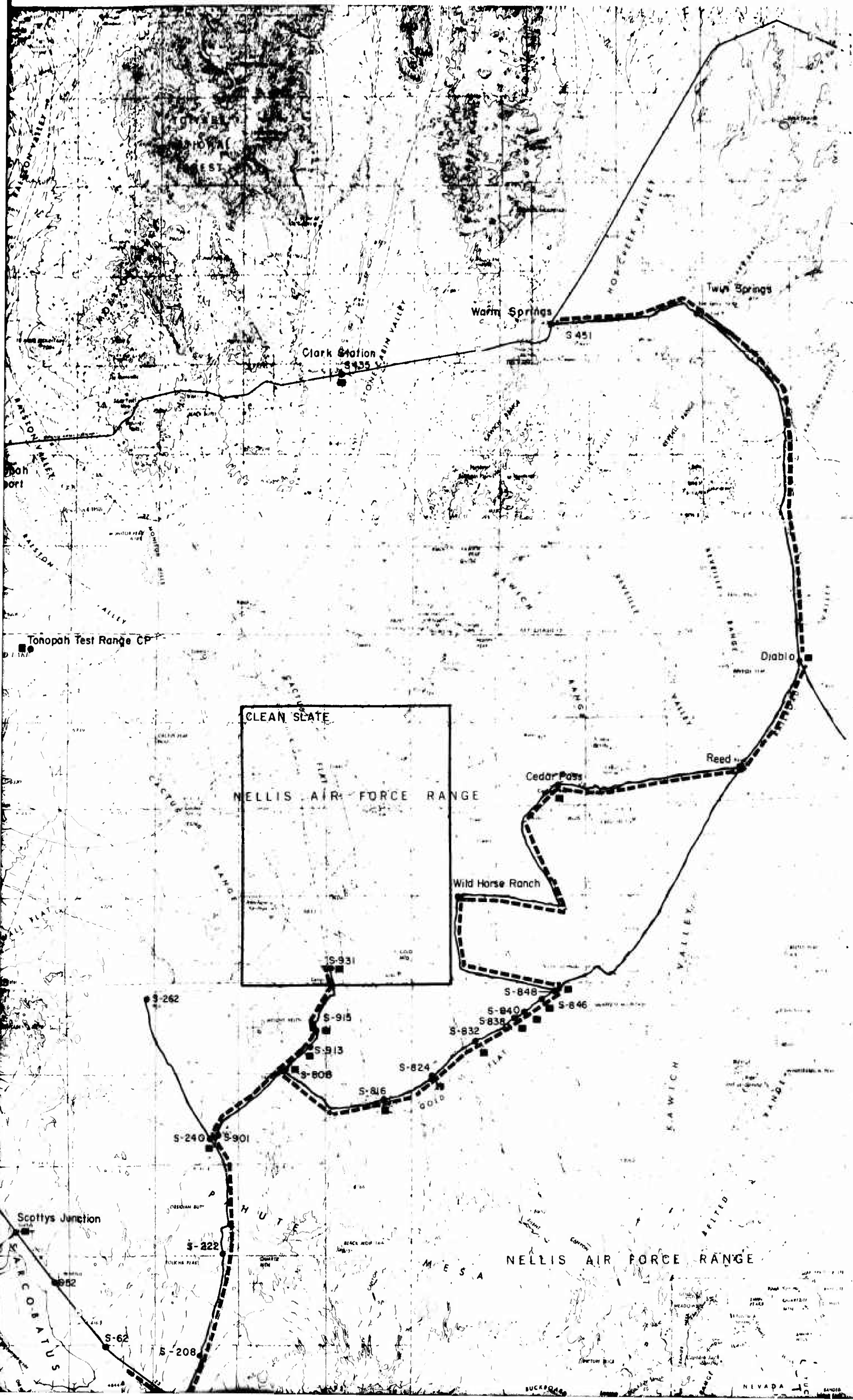
BERING SYSTEM, DOUBLE TRACKS EVENT. D

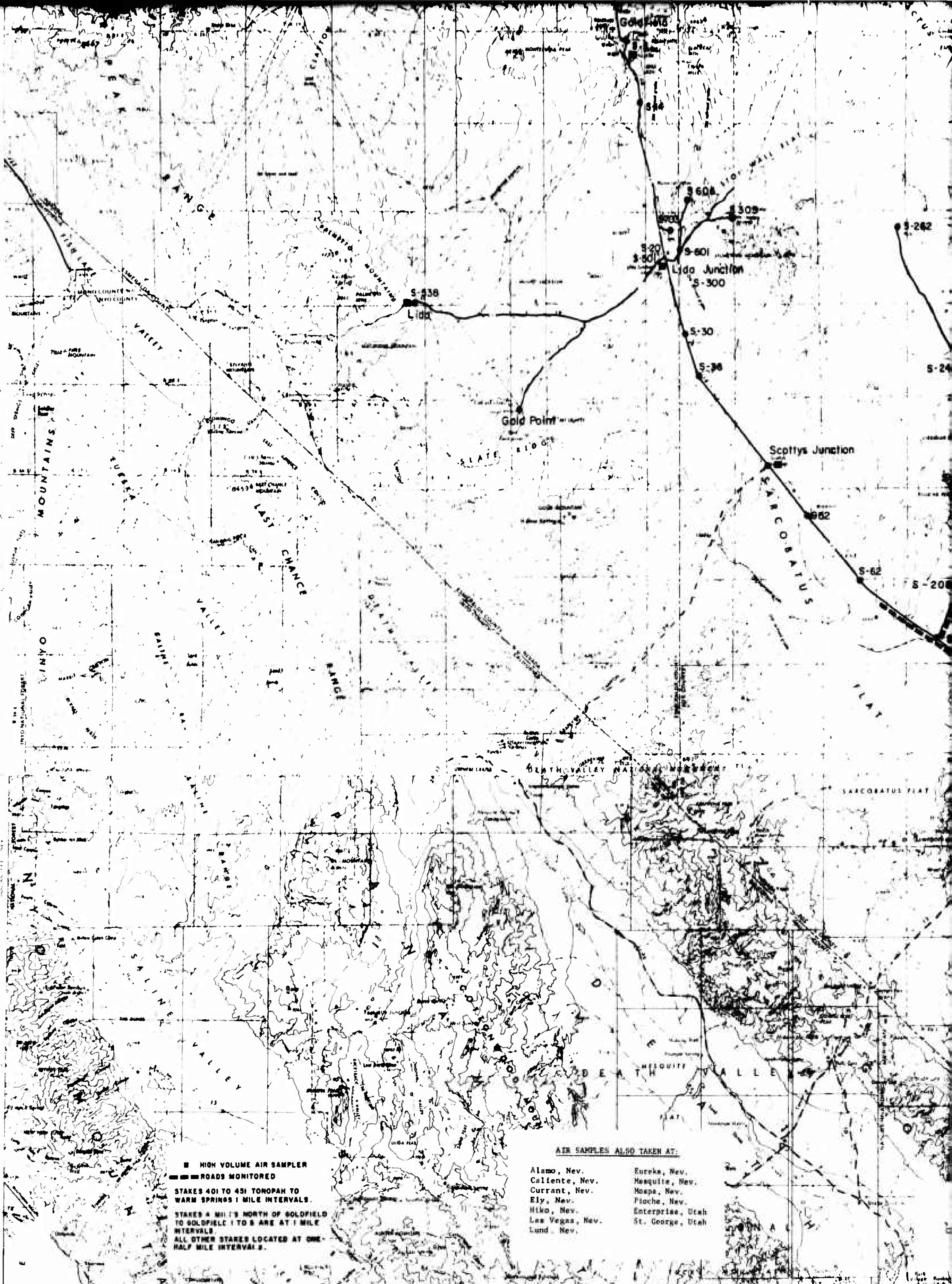
A



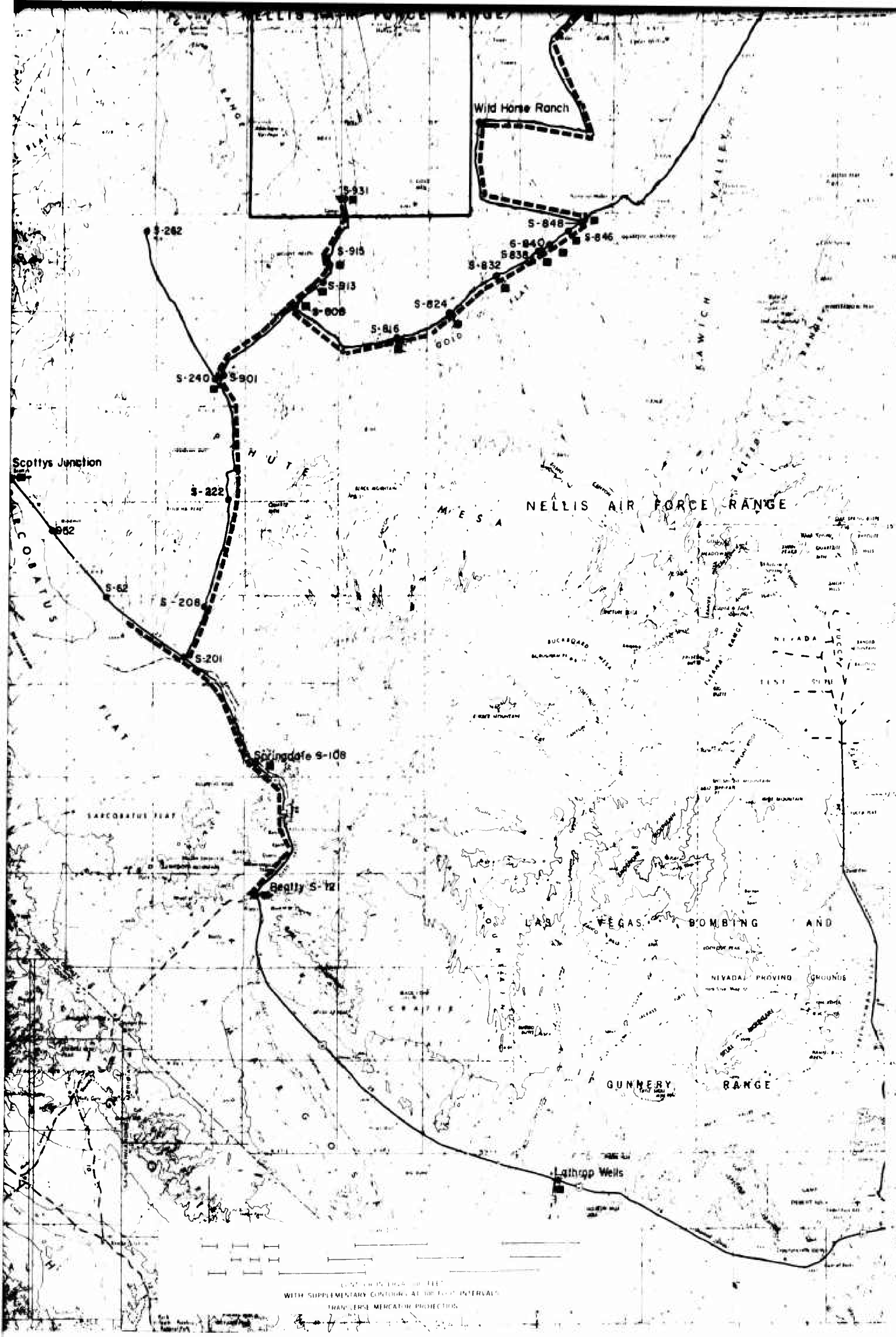
BIG SMOKY VALLEY
RALSTON VALLEY
Tonopah
Tonopah Airport
Tonopah Test Range CP
S-1
Goldfield
STONEWALL FLAT
S-606
S-303
S-262
S-20
S-501
S-601
Lida Junction
S-300
S-538
Lida
S-30
S-36
Gold Point
SLATE RIDGE
Scottys Junction
SARCOBATUS
S-62
S-208
S-24
SILVER PEAK RANGE
LAST CHANCE

B


Warm Springs
S 451
Twin Springs
Clark Station
S 455
STONE CABIN VALLEY
RALSTON VALLEY
Tonopah Test Range CP
Diablo
Reed
Cedar Pass
CLEAN SLATE
NELLIS AIR FORCE RANGE
Wild Horse Ranch
S-931
S-262
S-915
S-913
S-808
S-816
S-824
S-832
S-838
S-840
S-846
S-848
GOLD FLAT
KAWICH VALLEY
KAWICH RANGE
CACTUS RANGE
S-240
S-901
PAHUTE MESA
Scottys Junction
SARCOBATUS
S-222
S-208
S-62
962
NELLIS AIR FORCE RANGE
BELTED
NEVADA



(FIG. 2.2.) MARKING STAKE NUMBERING SYSTEM, CL



NG SYSTEM, CLEAN SLATE I, II, AND III.

D

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DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Defense Atomic Support Agency Washington, D.C. 20305	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

Off-Site Survey

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report of Project 2.8, Operation Roller Coaster

5. AUTHOR(S) (First name, middle initial, last name)

J. S. Coogan, Project Officer; D. L. Wait; S. J. Waligora, Jr.; U.S. Public Health Service, Southwestern Radiological Health Laboratory, Las Vegas, Nevada 89101

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
	97	26

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S) POR-2511 (WT-2511)
b. PROJECT NO. 2.8	
c.	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d.	

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

Operation Roller Coaster was a joint United States and United Kingdom experiment to determine plutonium hazards from accidents with plutonium bearing weapons. Four chemical detonations involved such weapons. The U.S. Public Health Service, through a Memorandum of Understanding with the U.S. Atomic Energy Commission and in conjunction with Project Roller Coaster, provided off-site radiological health surveillance. Detectable quantities of plutonium were released to off-site locations, but contamination levels did not present a significant hazard. Sampling methods are described and discussed with recommendations. The biological significance of plutonium is related to hazard evaluation. Certain recommendations are discussed for emergency procedures in the event of an accident.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Operation Roller Coaster						
Plutonium hazards						
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Plutonium bearings						
Radiological health surveillance						

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